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A43

sweep oscillator

MODEL 650

Serial 1621

File: S61

ALFRED ELECTRONICS 3176 PORTER DRIVE, PALO ALTO, CALIF.

INSTRUCTION MANUAL

QUALITY ASSURANCE
STANDARDS, CALIBRATION, AND MAINTENANCE LAB.

sweep oscillator

MODEL 650

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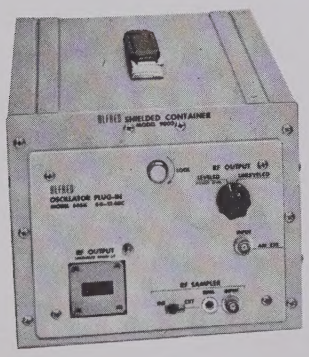

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INSTRUCTION MANUAL

QUALITY ASSURANCE
STANDARDS, CALIBRATION, AND
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evision Date	ECO#	Effective Serial's	Revision
3-26-68			In Figure 4-10, A6R24 and A6DS2 are replaced by a short circuit. The N.O. contact of A6K1 should show an arrow indicating connection to J7-2 in addition to the connection to DS-3.
4-1-68			On page 6-7, A9 Trans. Osc. Parts List, substitutes S/N 1490 for all references to S/N 1450 and substitute S/N 1491 for all references to S/N 1451.
4-29-68	#13547	S/N1450 & up	In Section 6, page 6-6, A6Q2 thru A6Q5 should read "Transistor, 2N697 (S/N 1449 & below) Transistor, 2N3565 (S/N 1450 & above). Alfred Part No. for Transistor 2N3565 is 81-115. Change Schematic 900757C-2 (Section 7) to show the change indicated above (A6Q2 thru A6Q5 should be 2N3565, not 2N697).
6-21-68		All	In Section 4, Fig. 4-13, add capacitor C12, .01 mfd. between the base and emitter of A3Q4 (2N3565).
6-21-68		All	In Section 4, Fig. 4-15, A4Q10 should be 2N404, not 2N3638A. In Section 6, p. 6-4, delete 2N3638A usage for A4Q4, A4Q10, and A4Q16. In Section 7, Schematic 900733C, change A4Q4, A4Q10, A4Q16 from 2N3638A to 2N404.
6-21-68		All	In Section 4, Figure 4-4, A2C3 should be .1 mf, not .01 μf.
6-28-68		All	In Section 4, Figure 4-16, change A9CR2 and A9CR1 to read 1N914, not 1N194.
7-24,68	13694	1589 & up	In the Parts List, Section 6, revise the A1 Cathode Supply Parts List as follows: Add: A1C4 12-15 Capacitor, ceramic, .002 mf. 1 KV A1C15 13-33 Capacitor, elect., 10 mf. 100 v Change: A1Q2 thru A1Q5 are 2N3643 Alfred part no. 81-188. A1Q2 thru A1Q5 were 2N3646 Alfred part no. 81-116. In Schematic 950770, Section 7, change the reference designator of A1Q2 thru A1Q5 from 2N3646 to 2N3643. Add A1C4 between the base of A1Q4 and the base of A1Q8. Also add A1C15 between terminals A and L on the same PC Board (positive lead of A1C15 at terminal L).
7-30-68	13711	1410 &up Optional below 1410)	On schematic 900775 and 900905, add capacitor A15C2 (.05 uf, 600 V) between pins A15-24 and A15-25. Also add capacitor A15C3 (.022, 500 V) between pins A15-20 and A15-21. On schematic 900775, add capacitor C23 (.001, 6 KV) between terminals 5 and 7 of T2. In the Main Chassis parts list, pg. 6-1, add C23, capacitor, fixed, ceramic, .001 uf, 6 KV (Part No. 12-28). In the A15 parts list, pg. 6-7, add A15C2, capacitor, fixed, ceramic, .05 uf, 600 V (Part no. 12-29); and A15C3, capacitor, fixed, ceramic, .022 uf, 500 V (Part No. 12-31).

Date	ECO#	Effective Serial's	Revisions
8-7-68	13723	All	In Section 6, Markers PC Board (A4) Parts List, add Transistor 2N3565, Alfred part no. 81-115 as alternate usage for A4Q1, A4Q2, A4Q7, A4Q8, A4Q13, and A4Q14 (Transistor, S6793, Alfred part no. 81-90). In Section 7, Schematic 900733, add as alternate usage for A4Q1, A4Q2, 7, 8, 13, 14 transistor 2N3565.
8-15-69		All	In Section 4, Figures 4-11 and 4-12, A15CR1 and A15CR2 should be MDA 920-6 (not MDA 950-6).
8-19-68	13737	S/N 1571 & up 1502-1511	In Section 6, A10 Parts List, make the following changes: A10R23 is 39 K, 2 w., was 68 K, 24 A10R24 is 39 K, 24; was 22 K Alfred part numbers for both A10R23 and A10R24 will be 43-39 K.
9-6-68		All	In Section 4, Figure 4-16, lower right corner of p. 4-31/4-32, change the ref designator and value of the resistor directly above A9CR5 to A9R5 - 82 Ω.
9-19-68	13768	1801 & up	In Section 6, A4 Parts List, add the following entries as alternate usage in S/N 1801 and up: A4R6 56-4.64 K Resistor, fixed, MF, 4.64 K, 1/2 w, 1% A4R9 56-2.87 K Resistor fixed, MF 2.87 K, 1/2 w, 1% In Section 7, change Schematic C900733 to reflect the above change in A4R6 and A4R9. In Section 4, Figure 4-15, change the Simplified Schematic to reflect the change in A4R6 and A4R9.
9-16-68	13772	All	Make the following changes in Table 1-2: Freq. Range — Column 1-2 GHz — Change the Power Output (mw) for Model 651CK to 40. Model 651C remains 60. 1.4 to 2.5 GHz — Change the Power Output (mw) for Models 651C-S1 and 651CK-S1 from 60 to 50. 2 - 4 GHz — Change the Power Output (mw) for Model 652 from 60 to 70. Change the Power Output (mw) for Model 652K from 50 to 60. Change the Power Output (mw) for Model 652CK to 30. Model 652C remains 40. 3.5-6.75 GHz. — Change the Power Output (mw) for Model 653CK-S1 to 15. Model 653C-S1 remains 20. 7-11 GHz — Change the Power Output (mw) for Model 654 from 40 to 35. Change the Power Output (mw) for Model 654K from 15 to 25.

Date	ECO#	Effective Serials	Revisions
9-16-68	13772	All	Freq. Range / Column 7 - 12.4 — Change the Power Output (mw) for Model 654-S1 from 40 to 35. Change the Power Output (mw) for Model 654K-S1 from 15 to 25. 8 - 12.4 Ghz. — Change the Power Output (mw) for Model 655 from 80 to 75.
9-27-8		All	In Section 5, Table 5-1, Group 1, the -50 V DC Voltage and tolerance should read -50 ± 2 V, not -50 ± 5 V.
10-9-8	13779	1681 and up	In the A 2 Parts List, Section 6, components A2C1 thru A2C5, and A2C9 should read "Alfred Part No. 14-30; Capacitor, fixed, mylar, 0.1 mf, 100 V.
10-24-68	13796	1610 & up	In the A1 Parts List, Section 6, delete Capacitor A1C14 AE Part No. 12-22, 100 pf. In the same Parts List, add the following: A1CR6 and A1CR7 — 81-132 Diode, 1N914 On Schematic 900770 in Section 7 add CR5 and CR6 in an opposing parallel configuration between the bases of dual transistor Q1. Also add CR7 between the emitter of Q7 and Δ5 with anode at emitter. Delete C14 on the same schematic.
11-13-8		All	In Section 4, Figure 4-9 (Heater Simplified Schematic), remove the jumper shown between Terminals A6-5 and A6-6 and insert a jumper connection between Terminals A6-5 and A6-4.

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SECTION 1

GENERAL INFORMATION

1.1 THE MODEL 650 SERIES SWEEP OSCILLATOR.

The Model 650 instrument operates as a sweep oscillator when combined with any one of a family of Oscillator Plug-in units, Models 651 through 659. The swept frequency output is a linear function of time, and both sweep width and sweep rate can be independently adjusted over a wide range. In addition to its swept rf output, the instrument can supply stable single-frequency signals, tunable anywhere in its frequency range, with stability rivaling that of mechanically-tuned signal generators. A large selection of Oscillator Plug-in units is provided, covering the frequency range from 250 Mc to 40 Gc. The plug-in units are completely interchangeable, so that any plug-in can be used with any Model 650 without readjusting or calibrating either the plug-in or the Model 650. This versatile operation is obtained because the 650 Series is designed so that all different voltages, biasing connections, etc., required by each different microwave tube are obtained from standard circuits in the main chassis through different dropping and feedback networks contained in the plug-in units. Thus, all Model 650 units are calibrated against a "standard" plug-in and all plug-in units are factory-calibrated to operate with the "standard" outputs from the Model 650.

All plug-in units contain a linearly calibrated frequency dial plate which is stored in the top of the plug-in chassis, and is attached to the dial panel of the Model 650 when that particular plug-in is used. A Model 9000 Storage Container is available for the plug-in units to provide convenient, antimagnetic protective storage when the unit is removed from the Model 650. For versatility, the Model 650 Series offers three sweep modes, three markers, five adjustable frequencies, internal and external modulation and leveling capabilities, display outputs, and other features.

The instrument provides two electronically controlled automatic sweeps (broadband and narrow-band symmetrical sweep), and manual sweep modes. The broadband sweep covers all or any portion of the full frequency range from 100% to 2%. During narrow-band symmetrical sweep operation, the frequency can be swept up to ± 5% of the full frequency range, about any desired center point. These sweeps can be triggered automatically in a free-running mode or from the line. An external trigger source or manual triggering also can be used. Sweep speed can be adjusted over a range of .01 to 100 seconds for the full frequency band. During manual sweep, the frequency can be manually swept over the full range of the instrument or between preset start and stop frequencies.

Frequency markers are available in all the sweep modes. Three rf modulated frequency markers are provided during leveled operation. They appear as rf absorption at the frequencies selected by the marker controls. If markers are needed when the rf power is unleveled, video pulse markers are available at the MARKER OUTPUT connector for combination with the rf detector output display.

Several voltages are available for oscilloscope and recorder control. For X-axis deflection of oscilloscopes and recorders a +15 V sweep voltage coincident with the rf sweep is available. A +50 V blanking signal is available during retrace. Also during retrace, at sweep speeds greater than 1 second, a relay with isolated S. P. D. T. contacts may be used to operate a recorder pen lift. The rf output may be either left on or turned off automatically during retrace.

The rf output may be amplitude modulated by either an external signal or an internally generated square wave. The square wave frequency is continuously adjustable from 800 to 1200 cps. Provision is made to permit externally controlled frequency modulation of the rf output. The rf output may be leveled across all or any portion of the band. The method of leveling and the provision of an internal leveling sampler depends upon the plug-in used. See Section 1.2 below.

The Model 650 instrument constitutes the main chassis which contains common power supply, frequency control, and modulation circuits, and an opening for one interchangeable plug-in unit. Specifications of the Model 650 Series Sweep Oscillators are given in Table 1-1. The microwave source used in the Model 650 Series is contained in the plug-in units, and is either a backward wave oscillator (BWO) or a voltage-tuned magnetron (VTM). Both tube types are encapsulated for protection and are easily replaced. Protective circuits reduce the likelihood of damage to the tubes. An internal time meter in each plug-in indicates hours of microwave tube operation.

1.2 THE OSCILLATOR PLUG-IN UNITS.

The Oscillator Plug-in units contain the rf components and the power supply coupling stages that connect the high voltage supplies and modulating circuits in the Model 650 to each tube.

The oscillator Plug-in units are divided into six groups: The Model 650 Series, the Model 650K Series, the Model 650A Series, the Model 650AK Series, the Model 650C Series*, and the Model 650CK Series*. These series differ in the type of rf leveling arrangements provided, as described below. Specifications and tube data for all Oscillator Plug-in units are given in Table 1-2.

1.2.1 THE MODEL 650 SERIES PLUG-IN UNITS. The Model 650 Series plug-in units provide an unleveled rf signal and cover the frequency range from 500 Mc to 40 Gc. They contain a leveler amplifier but do not contain an rf sampler component. Thus, the rf output can be leveled with an external sampler connected to the rf sampler input jack to drive the leveler amplifier. In the Model 650 Series, the leveling signal is coupled to the grid (BWO) or injector (VTM) of the microwave tube and the units are therefore designated as "grid leveled" type units. All modes of operation may be used in both the leveled and unleveled conditions. In the units operating below 12.4 Gc, the rf power output can be varied during leveled operation only. Above 12.4 Gc, a flap attenuator allows the power to be varied during unleveled operation also.

1.2.2 THE MODEL 650K SERIES PLUG-IN UNITS. The Model 650K Series plug-in units provide either a leveled or unleveled rf signal and cover the frequency range from 500 Mc to 18 Gc. They contain a leveler-amplifier and an internal rf sampling component. The leveler signal is coupled to the grid (BWO) or injector (VTM) of the microwave tube so that these units are also designated as "grid leveled" type units. The Model 650K Series also allows use of an external sampling component to level the rf signal at the load. A front panel switch selects either internal or external sampling. All modes of operation

*The Model 650C and 650CK are later production series containing an improved PIN diode leveler and which supersede the earlier 650A and 650AK Series in frequency bands above 1 Gc.

Table 1-1 Specifications of Model 650 Series Sweep Oscillators

Frequency Range: 0.25 to 40 Gc with appropriate Oscillator Plug-in unit(s) (see Table 1-2).

Leveling: Closed loop feedback control system provides leveling; mode of operation depends upon oscillator plug-in unit used:

Every Model 650 and 650K Series plug-in includes a leveler-amplifier connected for grid leveling. The Model 650 Series requires an external rf sampler for leveling rf power. The Model 650K Series includes the rf sampler mounted internally. A selector switch and BNC connector are provided on the front panel for external leveling.

Every Model 650A and 650AK unit and every Model 650C and 650CK unit includes a leveler-amplifier connected to an internal PIN diode leveler. The Model 650A and Model 650C Series requires an external rf sampler for leveling the output power. The Model 650AK and Model 650CK Series includes the rf sampler mounted internally. A selector switch and BNC connector are provided on the front panel for external leveling.

Power Level Control: 650K Series (all units) and 650 Series (below 10.0 Gc) are grid controlled and have power control available during leveled operation only. 650 Series (above 10.0 Gc) have power control during both leveled and unleveled operation. 650A, 650C, 650AK, and 650CK Series are PIN diode controlled and provide power control during leveled and unleveled operation.

Sweep Modes: Broadband sweep ($F_1 \rightarrow F_2$) continuously adjustable anywhere in the band. Symmetrical sweep ($F_0 \pm \Delta F$) adjustable from 0 to 10% of range anywhere in band, around an adjustable center frequency F_0. Manual sweep varies frequency between the limits set with controls F_1 and F_2.

Sweep Time: Continuously variable, 10 milliseconds to 100 seconds per sweep.

Sweep Recurrence Triggering Control: External, free running, line, or manual (single sweep). Panel button for manual triggering.

Single-Frequency Output Mode: Five stable single frequencies may be pre-set with controls F_0, F_1, F_2, M_1 and M_2, and selected interchangeably. This mode of operation permits use of the 650 Series Sweep Oscillators to replace mechanically tuned signal generators. The "single frequency" signals are stable within ±.004% (±.001% on some ranges), and external frequency or phase-locking discriminators can be used to obtain ultra-stable output.

Remote Frequency and Power Control: Available through use of 1000-ohm voltage dividers or potentiometers.

Sweep Output: 0 to 15 V sawtooth proportional to frequency during $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweeps. During F_0, M_1, and M_2 single-frequency operation, 0 to 15 V output is proportional to frequency. During manual sweep, output varies linearly 0 to 15 V as frequency is varied from F_1 to F_2.

Blanking Output and Pen Lift: +50 V signal available during sweep retrace. Pen lift relay S. P. D. T. contacts operated during sweep retrace on two slowest sweep ranges.

Rf Retrace On-Off: Rf signal on or completely off during retrace.

Frequency Markers: M_1, M_2 and F_0. Available either as pips in rf signal or as video pulses.

Frequency Stability: Better than 0.01% per degree C.

Internal Amplitude Modulation: Square wave, adjustable from 800 to 1200 cps.

External Amplitude Modulation: For leveled operation, or for slow-speed on-off keying in unleveled operation, +10 V will turn on rf signal to pre-set power level. For pulse modulation in unleveled operation, a greater voltage, depending on the plug-in, is required for full on-off. This is less than 50 V for 1 to 8 Gc and less than 100 V for 7 to 40 Gc.

External Frequency Modulation: 15 V peak-to-peak deviates frequency over full range. Response, approximately dc to 10 kc. High-frequency fm requiring greater drive voltage is available through helix modulation in BWO plug-in units. A maximum of 100 V peak-to-peak is required.

Spurious Signals: Non-harmonic 40 db, harmonic 20 db below rated output.

Power Input: 105 to 125 V or 210 to 250 V, 50/400 cps. Approximately 150 voltamperes.

Mounting Data: Removable cabinet sides permit rack-mounting.

Dimensional Data: Refer to the installation outline drawing, Figure 1-1.

can be used in both the leveled and unleveled conditions. The power can be varied during leveled operation only.

1.2.3 THE MODEL 650A and 650C SERIES PLUG IN UNITS

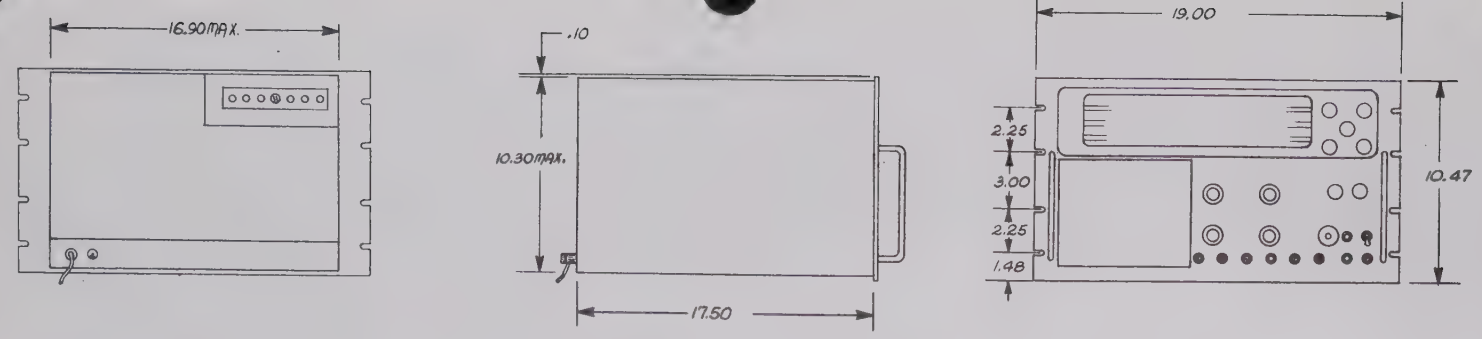
The Model 650A and 650C Series plug-in units provide an unleveled rf signal and cover the frequency range from 250 Mc to 12.4 Gc. They contain a leveler amplifier but do not contain an rf sampler component. Thus, the rf output can be leveled with an external sampler connected to the rf sampler input jack to drive the leveler amplifier. In the Model 650A and 650C Series, the leveling signal is coupled to a PIN diode attenuator which provides the leveling. Hence, these units are designated as "PIN diode leveled"or "solid state leveled" type units. All modes of operation can be used in both the leveled and unleveled conditions and the power can be varied in both conditions.

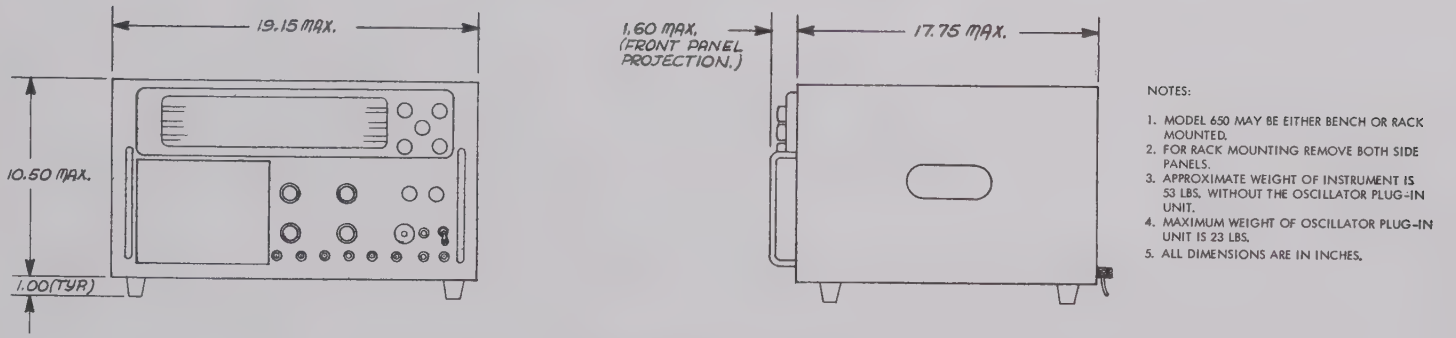
1.2.4 THE MODEL650AK and 650CK SERIES PLUG-IN UNITS.

The Model 650AK and 650CK Series plug-in units provide either a leveled or unleveled rf signal and cover the frequency range from 250 Mc to 12.4 Gc. They contain a leveler-amplifier and an internal rf sampling component that is coupled to a PIN diode attenuator which provides the leveling. Hence, these units are designated as "PIN diode leveled" or "solid state leveled" type units. The Model 650AK and 650CK Series also allows use of an external sampling component to level the rf signal at the load. A front panel switch selects either internal or external sampling. All modes of operation can be used in both the leveled and unleveled conditions, and the power can be varied in both conditions.

1.3 THE MODEL 650 SERIES POWER SUPPLY PLUG-IN UNIT.

Also available in the Model 650 Series is a Power Supply Plug-in unit, the Model 650-P1. When combined with a Model 650, it provides an instrument which operates as a sweeping cathode power supply which can be swept over all or any part of the range -150 V to -2500 V with respect to ground, and also provides a complete set of biasing signals for BWO's, VTM's or other microwave tubes having similar power requirements. Specifications for this plug-in unit are given in Table 1-3.




19.15 MAX.
10.50 MAX.
1.00 (TYP.)
1.60 MAX. (FRONT PANEL PROJECTION.)
17.75 MAX.
NOTES:
1. MODEL 650 MAY BE EITHER BENCH OR RACK MOUNTED.
2. FOR RACK MOUNTING REMOVE BOTH SIDE PANELS.
3. APPROXIMATE WEIGHT OF INSTRUMENT IS 53 LBS. WITHOUT THE OSCILLATOR PLUG-IN UNIT.
4. MAXIMUM WEIGHT OF OSCILLATOR PLUG-IN UNIT IS 23 LBS.
5. ALL DIMENSIONS ARE IN INCHES.
INSTRUMENT WITH SIDE PANELS INSTALLED.

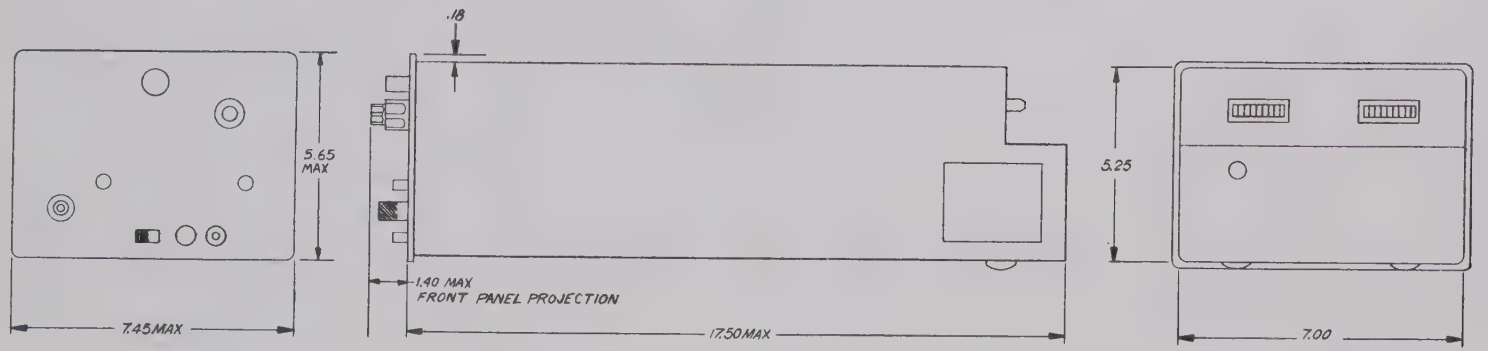


FIGURE 1-1. MODEL 650 INSTALLATION DRAWING

Table 1-2. Specifications of 650 Series Oscillator Plug-in Units.

	GRID LEVELED						PIN DIODE LEVELED						
FREQUENCY GHz	Model*	Plug-in Unit Instruction Manual	Tube Type and Vendor**	Power Output mw	Power Variation Leveled-db**	Price	Model*	Plug-in Unit Instruction Manual††	Tube Type and Vendor**	Power Output mw	Power Variation Leveled-db**	Price	TUBE NO.
0.25 to 0.5							651A-S2 651AK-S2	-7	VTM-EIM	25 20	- - ± 0.3	1875 2350	EM-1301
0.5 to 1.0							651A-S3 651AK-S3	-7	VTM-EIM	50 40	- - ± 0.3	1875 2350	EM-1312
1 to 2	651 651K	-1	BWO-STW	80 70	- - ± 0.3	1800 2090	651C 651CK	-6	BWO-STW	60	- - ± 0.3	2025 2300	SE214C
1.4 to 2.5	651-S1 651K-S1	-1	BWO-STW	80 70	- - ± 0.3	2050 2350	651C-S1 651CK-S1	-6	BWO-STW	60	- - ± 0.3	2325 2625	SE219-3
1.7 to 4.2	652-S5 652K-S5	-1	BWO-STW	35 30	- - ± 0.5	1925 2275	652C-S5 652CK-S5	-6	BWO-STW	15	- - ± 0.5	2150 2525	SE215-6
2 to 4	652 652K	-1	BWO-STW	60 50	- - ± 0.3	1600 1875	652C 652CK	-6	BWO-STW	40	- - ± 0.3	1850 2130	SE215A-2
3.5 to 6.75	653-S1 653K-S1	-1	BWO-STW	40 30	- - ± 0.4	1990 2500	653C-S1 653CK-S1	-6	BWO-STW	20	- - ± 0.4	2200 2700	SE221-1
4 to 8	653 653K	-1 (STW)/ -3 (VA) or	BWO- STW/VA	40 25	- - ± 0.5	1550 1900	653C 653CK	-6	BWO- STW/VA	15	- - ± 0.5	1800 2150	SE211A-8 (VA160A)
3.7 to 8.3	653-S2 653K-S2	-1	BWO-STW	10	- - ± 0.5	1850 2225	653C-S2 653CK-S2	-6	BWO-STW	5	- - ± 0.5	2100 2450	SE211B-7
7 to 11	654 654K	-3	BWO-VA	40 15	- - ± 0.5	1600 1975	654C 654CK	-6	BWO-VA	10	- - ± 0.5	1900 2300	VA173A
7 to 12.4	654-S1 654K-S1	-3	BWO-VA	40 15	- - ±0.75	1750 2150	654C-S1 654CK-S1	-6	BWO-VA	10	- - ±0.75	2050 2450	VA173A
8 to 12.4	655 655K	-3	BWO-VA	80 50	- - ± 0.5†	1550 1950	655C 655CK	-6	BWO-VA	20	- - ± 0.5†	1825 2200	VA173E
10 to 15.5	656	-5	BWO-VA	35	- -	2300							VA177A
12.4 to 18	657 657K	-5	BWO-VA	40 25	- - ± 0.8	1650 2175							VA162A
18 to 26.5	658	-5	BWO-VA	20	- -	2400							VA163A
26.5 to 40	659	-5	BWO-VA	>5	- -	4100							VA164A

†8.2 to 12.4 GHz; ± 0.7 for 8.0 to 12.4 ††Earlier 650A or 650AK Series with Stewart tubes use the -2 manual. Earlier 650A or 650AK Series with Varian tubes use the -4 manual.

*K suffix indicates rf leveling sampler mounted internally. Basic model and A-suffix model require an external rf sampler for leveling.

**Level variation limits shown for units with internal leveler-sampler can be achieved with at-the-load leveling in all units, by use of a suitable external sampler. Specifications and prices subject to change without notice. Data not shown was unavailable at press time.

**Tube Type and Vendor Code

BWO = Backward Wave Oscillator STW = Stewart VA = Varian E M = Eimac

Table 1-3. Specifications of Model 650-P1
Plug-in Power Supply

CATHODE SUPPLY

Voltage: -150 to -2500 V. Cathode supply can be operated at any fixed voltage or can be swept over any range between -150 and -2500 V. Voltage varies exponentially with time. Dial calibration is logarithmic. (Other voltage ranges and voltage curves are available on special order.) *

Current: 25 ma maximum.

Ripple: 15 mv peak to peak or .002% peak to peak whichever is greater (3 cycles to 250 kc).

Regulation

Load: 0.75 V from no load to full load. (Recovery time is less than 30 microseconds.)

Line: ± 0.1% for 10 V line variation.

Flyback Recovery Time: 4 milliseconds from -2500 to -150 V with no load (less with load).

Dial Calibration: ± 1%

ANODE SUPPLY

Voltage: Adjustable to any value between 35 and 280 V.

Current: 10 ma at 35 V, 1 ma at 280 V (varies linearly with voltage).

Ripple: Less than 2 mv peak to peak.

Regulation: ± 100 mv or ± 0.1%, whichever is greater, for ± 10 V line variation.

Calibration Accuracy: ± 1%

GRID SUPPLY

Voltage: Unmodulated; 0 to 100 V, adjustable. Modulated; 0 to 80 V adjustable.

Current: 1 ma maximum.

Ripple: Less than 15 mv peak to peak.

Regulation: Less than ± 100 mv for ± 10 V line variation.

Calibration Accuracy: ± 1 %

Modulation: Rise and fall time: 20 microseconds. Source impedance: less than 3 K. Internal square wave modulation is provided from the basic Model 650.

The negative side of the anode supply is permanently connected to the positive side of the grid supply. Thus, by connecting the cathode to one of the anode or grid supply terminals, it is possible to obtain various anode and grid supply voltages.

HELIX

Overcurrent Protection: Connected to ground through 35 ohms to provide overcurrent protection.

Overcurrent Trip: Adjustable from 3 ma to 25 ma.

COLLECTOR SUPPLY

Voltage: +100 V dc, ± 3%, relative to helix (ground).

Current: 25 ma maximum.

Ripple: Less than 1 mv peak to peak.

HEATER SUPPLY

Voltage: 6.3 V dc ± 1%

Current: 2 amperes maximum.

Ripple: Less than 25 mv peak to peak.

Regulation: Less than ± 0.2 V with load variation of 0 to 2 amperes.

* On special order any voltage range between the limits of -150 V and -2500 V can be provided. Also, special curves of voltage versus sweep time can be provided between linear and exponential (d^2v/dt^2 must be positive or zero). Dial may be calibrated in voltage or frequency.

1.4 SCOPE OF THE MODEL 650 SERIES INSTRUCTION MANUALS.

This Instruction Manual provides detailed descriptive data, operating instructions, circuit theory, and servicing information for the Model 650 instrument, and general information covering interface with the plug-in units. This manual can be used alone for operating the Model 650 instrument with any oscillator plug-in unit. More detailed theory and servicing information for each plug-in unit is given in the separate Oscillator Plug-in Instruction Manuals. There are eight different manuals for plug-in units identified by dash numbers in Table 1-2, which cover "families" of plug-in units having similar microwave tubes and leveling provisions. Each of these manuals includes both data applicable to the entire "family" and specific information for each model plug-in.

A separate manual is provided for the Power Supply Plug-in unit. It contains operating instructions for the Model 650 when used with that plug-in unit.

1.5 APPLICATIONS OF THE MODEL 650 SERIES.

By offering both swept-frequency and stable fixed-frequency output, with many modulation and control options, the Model 650 Series instruments can fulfill practically any requirement for microwave signal generation. They can be used to drive advanced swept-frequency test setups or for precision single-frequency tests. They can be amplitude-modulated, pulse-modulated, frequency-modulated, and remote-programmed to meet special systems requirements. Detailed operating instructions for use of the instrument in its various operating modes are given in Section 3. Contact the factory or your ALFRED representative if you need information regarding special applications.

SECTION 2

INITIAL INSTRUCTIONS

2.1 RECEIVING INSPECTION. Upon receiving your Model 650 with an installed Oscillator Plug-in unit, carefully unpack the instrument and check for shipment damage. If some damage is evident, file a claim against the carrier. Refer to the Shipment Damage Claim form in the back of this manual.

CAUTION

THE PLUG-IN UNIT CONTAINS A MICROWAVE TUBE WHICH IS EXTREMELY SENSITIVE TO FERROUS MATERIAL. USE ONLY NON-MAGNETIC SCREWDRIVERS AND OTHER TOOLS WHEN WORKING AROUND THE PLUG-IN UNIT, AND REMOVE YOUR WRIST WATCH TO AVOID MAGNETIC DAMAGE TO IT. WHEN REMOVED FROM THE MODEL 650, THE PLUG-IN UNIT SHOULD BE KEPT AT LEAST SIX INCHES FROM MAGNETIC MATERIALS.

2.2 SHIPPING SCREWS. The installed plug-in unit is secured to the Model 650 for shipping with four screws, two located underneath the unit and two at the rear (Figure 3-2). They are used to prevent plug-in damage. Prior to regular use of the unit, these screws must be removed. They are easily identifiable by arrows marked on the rear and bottom of the cabinet. An aluminum shipping plate is installed over the dial plate area of the panel to protect the dial indicator mechanism. Remove this plate by removing its two knurled attaching screws, to allow installation of the frequency dial plate contained in the plug-in unit.

2.3 POWER REQUIREMENTS. The unit is normally connected at the factory for operation at 105 to 125 V ac (115 V ac nominal) and 50 to 400 cps. However, provisions are provided for easy conversion to operation at 210 to 250 V ac (230 V ac nominal). With the top cover removed, locate the power switch labeled 115 VAC (Figure 5-1). Remove the plate and move the switch forward to its alternate position. Turn the plate over and replace it with 230 VAC showing. To reconvert for 115 V ac operation, reverse the above procedure.

2.4 CHASSIS GROUNDING. The instrument is supplied with a three-conductor power cord and a three-prong plug, which grounds the instrument when plugged into an appropriate receptacle. If a three-prong to two-prong adapter is used, make sure the unit is properly connected to ground by grounding the adapter pigtail lead.

WARNING

FAILURE TO PROPERLY GROUND THE INSTRUMENT CAN DEGRADE ITS PERFORMANCE AND STABILITY, AND COULD ALLOW AN ABOVE-GROUND POTENTIAL TO BUILD UP ON THE CHASSIS, WHICH COULD BE DANGEROUS TO OPERATING PERSONNEL.

2.5 COOLING. Adequate space must be provided at the top, rear and bottom of the unit for cooling purposes. Although most of the Model 650 Series oscillator plug-in units do not require forced air cooling, due to use of all-solid-state components in most circuits, proper ventilation for convection cooling is required, with one inch at the top and one-half inch at the bottom.

2.6 CHECKING INSTALLED POSITION OF FREQUENCY DIAL PLATE. (See Figures 2-1 and 3-1.) At the low-frequency end of the frequency dial plate, at both top and bottom, there are calibration markers consisting of a transparent circle partially bisected by the black line which denotes the low-end frequency. The proper calibrated position of the dial plate is with these circles positioned so they are centered on the white line behind the plate (on the dial plate area of the panel). This aligns the low-end frequency marks with these white calibration lines. Check whether the dial plate has shifted from the calibration position during shipping. If necessary, loosen the two attaching thumb screws and move the frequency dial plate sideways as required to achieve this calibrated alignment. Then retighten the two thumb screws. The instrument is now calibrated to the frequency range of the oscillator plug-in from which the dial plate was removed.

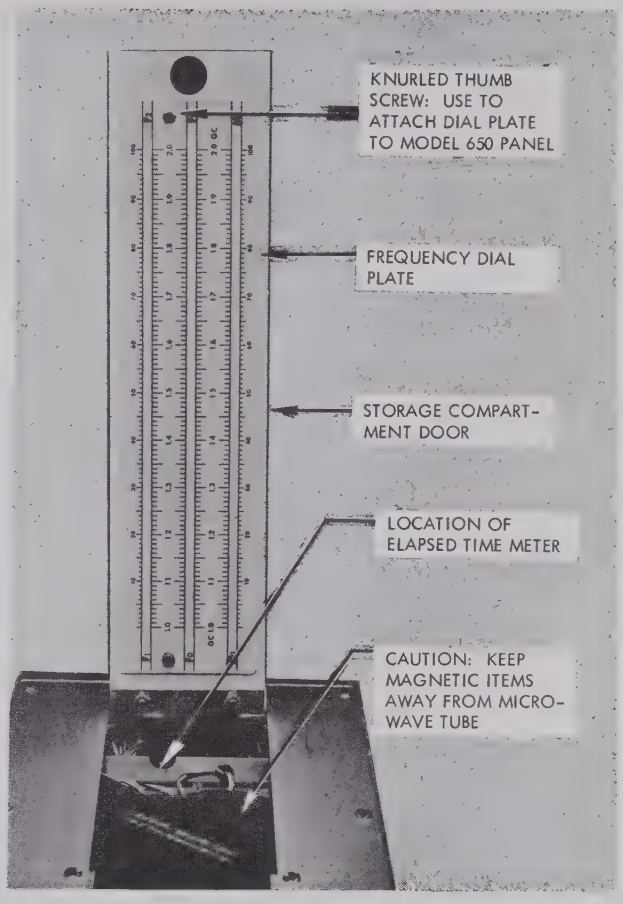

KNURLED THUMB SCREW: USE TO ATTACH DIAL PLATE TO MODEL 650 PANEL
FREQUENCY DIAL PLATE
STORAGE COMPARTMENT DOOR
LOCATION OF ELAPSED TIME METER
CAUTION: KEEP MAGNETIC ITEMS AWAY FROM MICROWAVE TUBE

FIGURE 2-1. TOP VIEW OF TYPICAL OSCILLATOR PLUG-IN UNIT SHOWING STORED POSITION OF FREQUENCY DIAL PLATE.

NOTE: Be sure the proper frequency dial plate, corresponding to the plug-in unit installed, is used. When the Model 650 is shipped with an aluminum shipping plate installed in the dial plate area, or if a different plug-in is to be used, install and calibrate the frequency dial plate stored in the top storage compartment (Figure 2-1) of the plug-in unit to be used, as described above. To remove and install plug-in units, and/or for access to the dial plate storage compartment, remove the plug-in unit by turning the LOCK knob fully CCW. When a plug-in unit is reinstalled, the LOCK knob must be turned CW only after the plug-in unit is pushed all the way in; otherwise the interlock switch associated with the locking device will keep the instrument off.

2.7 INCOMING INSPECTION TEST.

CAUTION

MANY INTERNAL ADJUSTMENTS LOCATED WITHIN THE MODEL 650 CHASSIS ARE CRITICAL. THEY HAVE BEEN CAREFULLY FACTORY-ADJUSTED PRIOR TO SHIPMENT AND SHOULD NOT NEED FIELD ADJUSTMENT. BECAUSE OF THE INTERACTION OF THESE ADJUSTMENTS A COMPLETE REALIGNMENT MAY BE REQUIRED IF THEY ARE DISTURBED. REFER TO SECTION 5 OF THIS MANUAL BEFORE TOUCHING ANY ADJUSTMENTS.

The following inspection test may be performed prior to regular operation of the Model 650. In each step, leave switch settings as made previously unless instructed otherwise.

2.7.1 FREQUENCY CHECK.

a. Make the following panel control settings:

FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Selector to F_0
MODULATION Selector to AM OFF
RF OUTPUT switch to UNLEVELED
POWER LEVEL control to MAXIMUM clockwise position
F_0 FREQUENCY indicator to the low-end frequency on the dial
Turn POWER switch to ON.

NOTE: A time delay relay delays application of high voltage for approximately 60 seconds after the power switch is turned on. This is to allow a brief warm-up period for the microwave oscillator tube filament. If the ac power is off for even an instant, the normal 60-second delay will occur before the high voltage returns after turn-on.

b. Connect the RF OUTPUT connector through a suitable frequency meter and attenuator pads to a video detector. Connect the detector output to the vertical channel of an oscilloscope. Set the scope for self-triggering.

CAUTION

THE RF POWER OUTPUT CAN BE AS GREAT AS 300 MW (BWO UNITS) OR 10 W (VTM UNITS). DO NOT EXCEED THE MAXIMUM POWER RATING OF THE DETECTOR. SUITABLE PADS SHOULD BE USED TO REDUCE THE OUTPUT POWER AND THUS PROTECT THE DETECTOR.

c. Check the frequency by observing the drop of the scope trace as the frequency meter is moved through the output frequency. Repeat the check using several F_0 settings across the band. The reading on the frequency meter should be within 1% of the frequency indicated on the dial. If not, refer to Section 5 for recalibration.

2.7.2 SWEEP VOLTAGE CHECK.

a. Make the following panel control settings:

FREQUENCY Mode Selector to SWEEP; $F_1 \rightarrow F_2$
SWEEP TIME to .01 seconds; and concentric VARIABLE Control fully clockwise (CAL position).
SWEEP TRIGGER Selector to LINE.

b. Connect an oscilloscope to the SWEEP OUTPUT jack using dc coupling. The signal observed should be a sawtooth with an amplitude of exactly 15 volts peak-to-peak.

2.7.3 RF OUTPUT CHECK.

a. Make the following panel control settings:

F_1 FREQUENCY indicator to 0 (low end of scale).
F_2 FREQUENCY indicator to 100 (high end of scale).
FREQUENCY RETRACE to OFF.

b. Connect a video detector to the RF OUTPUT connector using suitable pads, as in 2.7.1, and connect the detector output to the vertical channel of an oscilloscope.

c. Connect the SWEEP OUTPUT jack to the horizontal deflection channel of the oscilloscope.

d. Visually check the unleveled rf output across the band.

2.7.4 LEVELER CHECK IN "K" OR "AK" TYPE UNITS. (For other units, skip to 2.7.5.)

a. Set the RF OUTPUT switch to LEVELED, and the RF SAMPLER switch to INTERNAL.

b. Observe the rf output with an oscilloscope connected as in 2.7.3.

c. Rotate the POWER LEVEL control counterclockwise until the rf output is leveled, at which time the UNLEVELED light will go out.

d. Visually check the leveled rf output across the band.

2.7.5 MODULATION CHECK.

a. Make the following panel control settings:

MODULATION Selector to SQ WAVE

b. Observe the rf output with an oscilloscope connected as in 2.7.3. The display should be keyed on and off in a symmetrical square wave pattern.

2.7.6 TRIGGER CHECK

a. Turn the TRIGGER Selector switch to FREE RUN.

b. Observe the output with an oscilloscope connected as in 2.7.3. The automatic sweep should continue.

c. Turn the TRIGGER Selector switch to MANUAL.

d. Press the button in the TRIGGER Selector switch. One sweep should be obtained after each push of the button.

2.8 STORAGE OF PLUG-IN UNITS REMOVED FROM THE MODEL 650. Always store the Oscillator Plug-in unit in a suitable container, such as the ALFRED Storage Container, Model 9000, or on wood and at least six inches from magnetic sources.

2.9 RETURNING THE INSTRUMENT. If it becomes necessary to return the instrument to ALFRED ELECTRONICS, authorization must first be obtained from our Sales Department.

When authorization is received, prepare the instrument for shipment by removing the frequency dial plate from the panel and placing it in the storage compartment of the plug-in unit. Then install the plug-in unit in the Model 650 and secure with four shipping screws installed through the holes marked by arrows in the bottom and rear of the cabinet. A protective shipping plate or a piece of cardboard should be placed over the dial plate area for protection. A board or heavy cardboard buffer should be placed in front of the unit across the handles to protect the panel from blows against the container.

The instrument should be wrapped in a protective material such as polyethylene and heavy wrapping paper to protect against marring by the padding used in the container. A sufficient quantity of padding material, such as hair flex, should be placed all around the instrument for cushioning. If the

original shipping container is not available, an equivalent rugged cardboard container or wooden crate should be used for the packing carton. Pack the instrument so that it cannot move around in the container. A letter containing all pertinent information should be included in the package, unless such a letter has previously been sent to our Sales Department.

3.1 FRONT PANEL CONTROLS (See Figure 3-1).

A functional description of all front panel controls is given in Table 3-1. In the table, CW and CCW are used

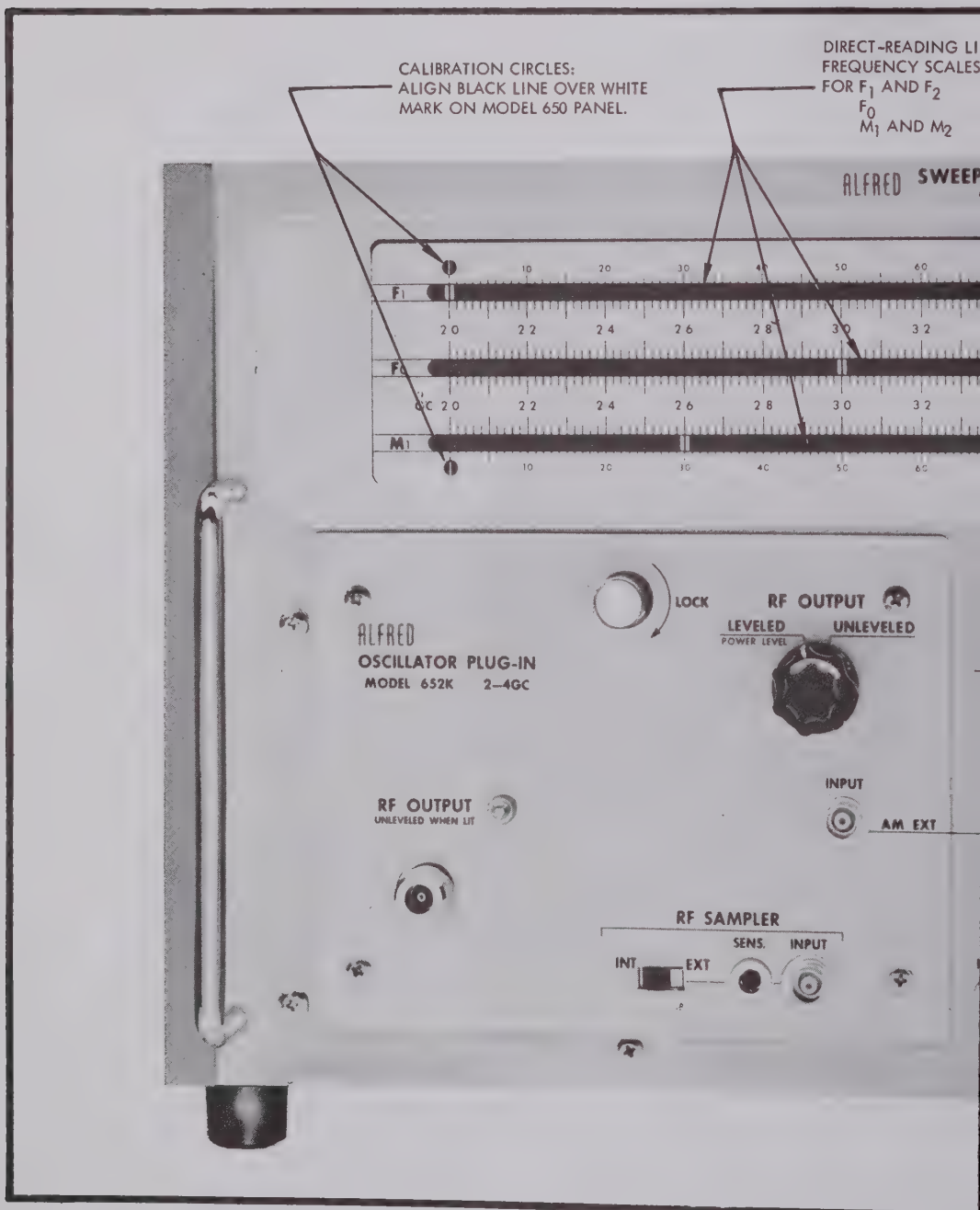
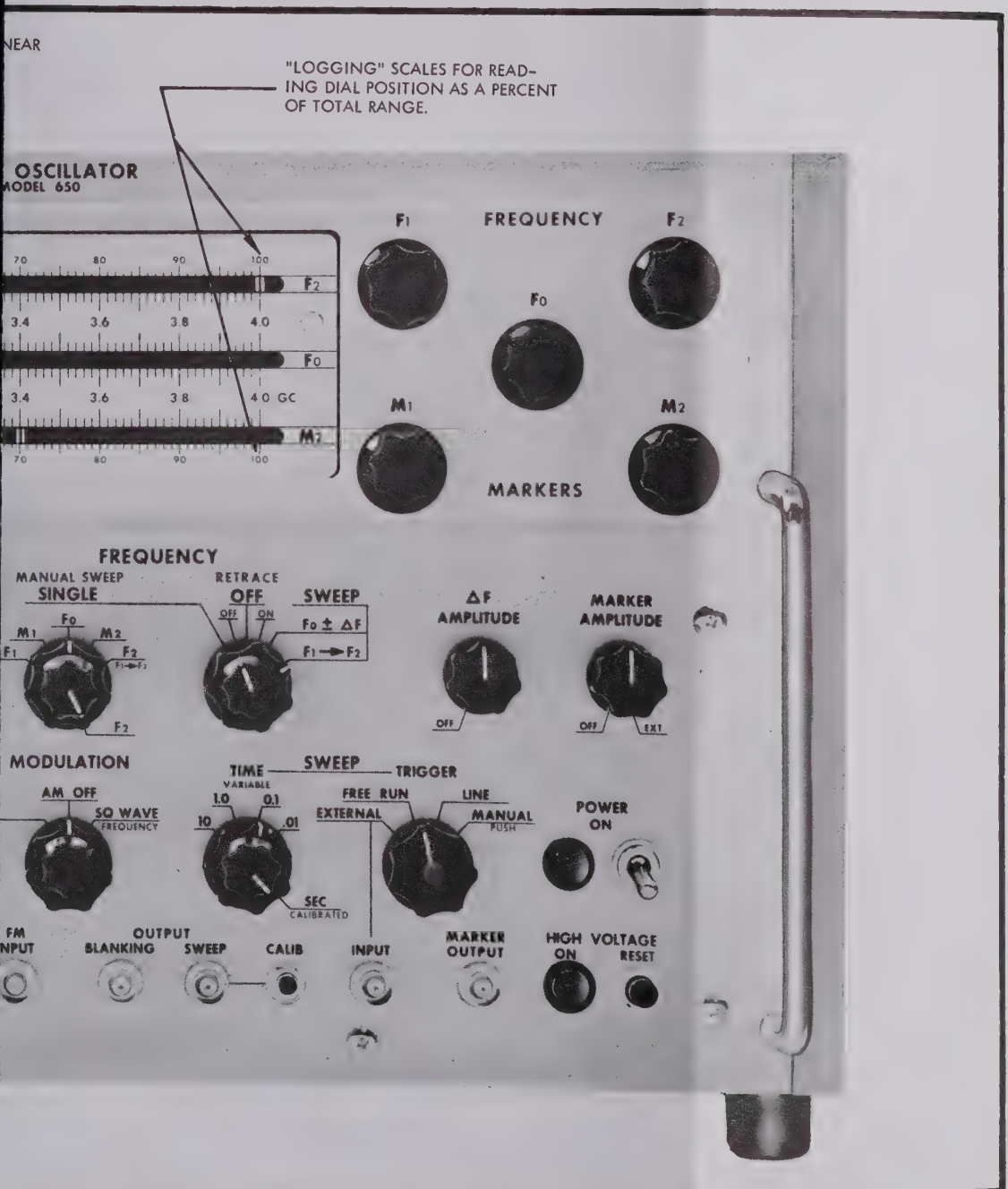


FIGURE 3-

o abbreviate clockwise and counterclockwise, respectively.



1. FRONT PANEL

Table 3-1. Description of Front Panel Controls and Indicators

Control or Indicator	Function
FREQUENCY Controls SINGLE-OFF-SWEEP Mode Selector Switch	In $F_1 \rightarrow F_2$ SWEEP position, provides a swept rf output starting at the F_1 frequency indicator setting and sweeping to the F_2 frequency indicator setting. The sweep speed and recurrence are controlled by other panel controls. The sweep frequency range (from F_1 to F_2) can be varied from 100% to 2% of the frequency band of the Oscillator Plug-in unit by use of the F_1 and F_2 FREQUENCY controls. When in this mode, marker pips are available at the F_0, M_1 and M_2 frequency settings. A sawtooth sweep voltage of +15 V amplitude is available at the SWEEP OUTPUT jack. The SWEEP light glows while each sweep progresses from F_1 to F_2. In $F_0 \pm \Delta F$ SWEEP position, the rf output is swept symmetrically about any F_0 frequency setting (starting at $F_0 - \Delta F$ and sweeping to $F_0 + \Delta F$). ΔF can be varied from 0 to ± 5% of the full frequency band by using the ΔF AMPLITUDE control. This narrow sweep mode may be used to examine small perturbations seen when using the $F_1 \rightarrow F_2$ mode, by setting F_0 to the perturbation frequency and switching to $F_0 \pm \Delta F$ mode. When in this mode, marker pips are available at the M_1 and M_2 settings, and the +15 V sawtooth is available at the SWEEP OUTPUT jack. The SWEEP light glows while each sweep progresses from $F_0 - \Delta F$ to $F_0 + \Delta F$. In OFF position, applies a modulating signal to the microwave oscillator tube, to turn off the rf output power. In single-frequency operation, the OFF position can be used to zero external meters and establish a zero power reference. In all modes of operation, the OFF position can be used to keep the instrument in a "standby" condition. By maintaining filament and cathode voltages during this "standby" condition, the microwave oscillator tube is continuously being outgassed. This tends to extend tube operating life by more than 10%. In SINGLE position, the oscillator output can be any one of five single frequencies determined by the F_0, F_1, F_2, M_1 or M_2 FREQUENCY and MARKER controls. The SINGLE Frequency Selector switch selects any one of the above frequencies for rf output.
RETRACE Selector Switch (Red)	Concentric with the Mode Selector switch, this switch is operative only in the swept-frequency modes of operation. In the OFF position, rf power output is removed during retrace; in the ON position, rf power is supplied during retrace.
SINGLE Sweep Frequency Selector Switch	This switch is operative only in the single-frequency mode of operation. It selects one of the FREQUENCY or MARKER controls to set the output frequency (F_0, F_1, F_2, M_1, or M_2).
MANUAL SWEEP Control (Red)	This control functions only when the SINGLE Sweep Frequency Selector switch is in the F_2 position. Concentric with that switch, this control can be turned clockwise to manually sweep the rf output from F_1 to F_2. At the extreme counterclockwise position, the output frequency is F_1. At the extreme clockwise position, the control actuates a switch which locks the output frequency at F_2.
FREQUENCY Dial Control Knobs F_1 and F_2	In the $F_1 - F_2$ sweep mode, these controls select the lower and upper limits respectively, of the sweep. In single-frequency mode, they can be used to select output frequencies for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting of each control is shown by the corresponding indicator bar in the frequency dial (F_1 to the left of F_2 in the $F_1 - F_2$ dial slot). Not operative in $F_0 \pm \Delta F$ sweep mode.
F_0	In $F_0 \pm \Delta F$ sweep mode, selects the center frequency about which the narrow symmetrical sweep is made. In $F_1 \rightarrow F_2$ sweep mode, and during manual sweep in the F_2 single-frequency mode, provides an absorptive marker pip (if adjusted to a frequency within the swept range). In single-frequency mode, can be used to select an output frequency for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting is shown by the F_0 dial indicator bar.
MARKERS Control Knobs M_1 and M_2	In $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweep modes, and during manual sweep in the F_2 single-frequency mode, these controls provide adjustable absorptive marker pips (if adjusted to a frequency within the swept range). In single-frequency mode, can be used to select two output frequencies for final selection by the SINGLE Sweep Frequency Selector switch. The frequency setting of each control is shown by the corresponding indicator bar in the frequency dial (M_1 to the left of M_2 in the $M_1 - M_2$ dial slot). NOTE: In single-frequency mode, the rf output may be swept manually by turning the FREQUENCY or MARKERS control selected by the SINGLE Sweep Frequency Selector switch.
ΔF AMPLITUDE Control	In the $F_0 \pm \Delta F$ sweep mode, adjusts the width of the symmetrical sweep about F_0. Provides maximum sweep width (± 5% of the full frequency band) in the fully clockwise position. Sweep width decreases to zero as the control is turned counterclockwise to OFF at the extreme CCW position, to provide fixed-frequency output at F_0. NOTE: The OFF position is at the CCW rotation limit; it is not a switched position.
MARKER AMPLITUDE Control	In the $F_1 \rightarrow F_2$ and $F_0 \pm \Delta F$ sweep modes, and during manual sweep in the F_2 single-frequency mode, sets the amplitude (absorptive peak height) of the rf markers that are visible in the swept rf output. The adjustment range provides maximum amplitude at the clockwise limit (before being switched to the EXT position). The EXT switch position at the CW limit of travel removes the marker pips from the rf output signal and makes available video marker pulses at the MARKER OUTPUT connector. These video marker pulses are negative-going pulses with a -1 V amplitude and a width of 5 μs. One pulse is supplied when the sweep crosses, M_1, M_2, and F_0. (Marker pulses are also supplied during retrace.) The OFF position at the CCW limit of travel turns off all marker signals. NOTE: The OFF position is at the CCW rotation limit; it is not a switched position.

Table 3-1. (Continued)

Control or Indicator	Function
MODULATION Controls MODULATION Mode Selector Switch	In SQ WAVE position, modulates the rf output with an internally-generated square wave which is adjustable in frequency betwen 800 and 1200 cps by means of the concentric red Frequency Vernier Control. Square-wave modulation amplitude is 0 to power level set for all leveled units, all 650C Series units, and all 650 Series units above 12.4 Gc; and 0 to full-on for all 650 Series units below 12.4 Gc. In AM EXT position, the rf output will be turned off until an external signal is applied. A +10 V signal applied to the AM EXT INPUT connector will turn on the rf signal output to the level set when operation is in leveled mode, and to the maximum output level during unleveled operation. (Higher levels are required for pulsed on-off control; see Paragraph 3.10.2.) In AM OFF position, eliminates all amplitude modulation. Frequency modulation can be used with this or any other position of the switch.
Frequency Vernier Control (Red)	Concentric with the MODULATION Mode Selector switch, this control adjusts the frequency of the internal square-wave modulation in the SQ WAVE modulation mode. Modulation frequency varies between about 800 cps in the full counterclockwise position to about 1200 cps in the full clockwise position.
SWEEP Controls SWEEP TIME Selector Switch	Selects the time required to sweep from the start frequency to the stop frequency in either automatic sweep mode ($F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$). With the red vernier control fully clockwise in the CALIBRATED position, the SWEEP TIME positions read directly in seconds (.01, 0.1, 1.0 and 10 seconds).
Sweep Time Vernier Control (Red)	Concentric with the SWEEP TIME Selector switch. When fully clockwise, calibrates that switch to read in seconds. When rotated counterclockwise out of the CALIBRATED position, slows the sweep to increase the sweep time by a factor up to about 10:1 at the fully CCW position. Allows a maximum sweep time of 100 seconds and continuous adjustment between all fixed sweep time settings. NOTE: The CALIBRATED position is at the CW limit of rotation; it is not a switched position.
SWEEP TRIGGER Selector Switch	In EXTERNAL position, a positive pulse signal applied to the EXTERNAL INPUT jack is required to trigger each sweep. Pulse amplitude must be at least +5 V, and pulse width must be at least 10 microseconds. In FREE RUN position, a new sweep is triggered immediately upon the completion of each sweep. Thus, the sweep is recurrent with a period equal to the SWEEP TIME setting. In LINE position, the sweep trigger is synchronized to the power line frequency. In MANUAL position, each sweep must be triggered by pressing the concentric button.
Manual Trigger Pushbutton (Red)	Concentric with the SWEEP Trigger Selector switch. Press to trigger a sweep in the MANUAL sweep mode. Not operative in other sweep modes.
POWER ON Toggle Switch	Turns power on when switched up; removes all power from the instrument when switched down. Adjacent POWER ON indicator glows when the instrument is energized.
HIGH VOLTAGE RESET Pushbutton	Press to reset high voltage after correcting overload condition.
HIGH VOLTAGE ON Light	Glows when high voltage is applied to microwave oscillator tube. When instrument is first turned on, there is a time delay of about 60 seconds before high voltage is applied.
RF OUTPUT Selector Switch (on Oscillator Plug-in)	Selects LEVELED or UNLEVELED operation. For leveled operation, external sampling inputs must be applied in the 650 and 650A Series plug-in units.
POWER LEVEL Control (Red)	Concentric with RF OUTPUT Selector switch. Sets output power level during leveled operation in all units, and during unleveled operation in the 650A, 650AK, 650C, and 650CK Series. Provides maximum power when fully clockwise; reduces output to the level that permits full-band leveling when turned to a mid-position, and then an additional 5 db (most plug-in units) when turned fully counterclockwise (10 db on C- and CK- Series).
UNLEVELED WHEN LIT Light (on Oscillator Plug-in)	Glows when rf output is unleveled. In leveled operation, glows when power is unleveled over any portion of the band being swept, indicating that the POWER LEVEL setting is too high, or the (external) sampler output is too low.
RF SAMPLER SENS Screwdriver Control (on Oscillator Plug-in)	When using an external rf leveling sampler, this control permits adjustment of the internal leveling amplifier sensitivity to match the external sampler output for optimum broadband leveling; see Paragraph 3.12.3. CAUTION USE ONLY NON-METALLIC SCREWDRIVER TO MAKE ANY ADJUSTMENTS ON PLUG-IN. FERROUS MATERIALS CAN DAMAGE THE MICROWAVE TUBE.
POWER LEVEL Control (Black) (only on Oscillator Plug-in units with output frequency above 12.4 Gc)	Adjacent to waveguide output flange on units with output frequency above 12.4 Gc. Operates waveguide flap attenuator to adjust output power level over a range of about 10 db in all modes of operation.
RF SAMPLER Snap Switch (only on Oscillator Plug-in units with internal sampling)	Selects INTernal or EXTernal sampling for leveled operation. For EXTernal sampling, the input from the external detector must be applied to the RF SAMPLER INPUT connector.

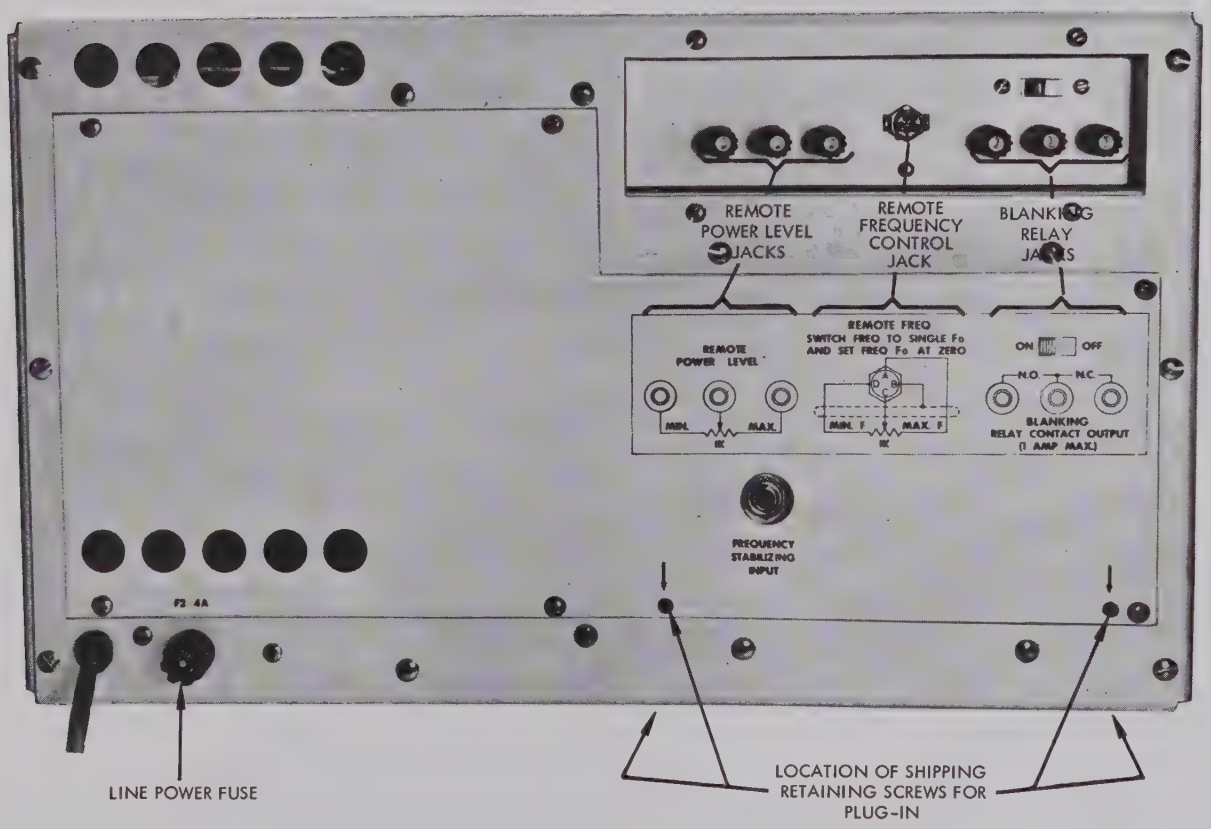


FIGURE 3-2. REAR PANEL

3.2 FRONT PANEL CONNECTORS (See Figure 3-1).

A functional description of all front panel connectors is given in Table 3-2.

Table 3-2. Description of Front Panel Connectors

Connector	Function
FM INPUT	Permits deviation of the rf output signal from the frequency set by the panel controls by using an externally-applied signal. A signal of 15 V peak-to-peak is sufficient to deviate the output over the full frequency range. Response is dc to 10 Kc. Input impedance is 15 K ohms.
BLANKING OUTPUT	Provides a +50 V signal during sweep retrace. Output impedance is 10 K ohms.
SWEEP OUTPUT	Provides a 0 to +15 V sawtooth synchronized with the rf output frequency in either swept or fixed-frequency modes. Output impedance is 10 K ohms. In the $F_1 \rightarrow F_2$ swept output mode, the sawtooth wave tracks the rf output, and is 0 volts at F_1, increasing to +15 V at F_2. In the $F_0 \pm \Delta F$ swept mode, the sawtooth runs the full 0 to +15 V range linearly as the rf output sweeps from $-\Delta F$ to $+\Delta F$. In the single-frequency modes, the output is a dc level linearly proportional to the dial frequency (0 V at low end; +15 V at high end) when M_1, F_0, or M_2 control the frequency output. In the F_2 single-frequency mode (during manual sweep), the output level varies linearly from 0 at a frequency corresponding to F_1 to +15 V at a frequency corresponding to F_2. In the F_1 single-frequency mode, no output is provided. NOTE: The sweep output level is switched to +15 V to permit calibration of the using device when the adjacent CALIB pushbutton is pressed.
EXTERNAL (TRIGGER) INPUT	Permits use of an external trigger signal to trigger each rf output sweep. A signal of +5 V minimum, with a duration of at least 10 μs, actuates the sweep. Input impedance is greater than 10 K.
MARKER OUTPUT	Supplies marker output pulses when the rf output frequency crosses the value set by each FREQUENCY MARKER control (M_1, M_2, and F_0) in any swept mode of operation. The pulses have a -1 V amplitude and a width of 5 μs. Output impedance is 1 K ohm. They are supplied only when the MARKER AMPLITUDE control is turned fully CW to the EXT switched position.
AM EXT (on Oscillator Plug-in)	Permits input of an external signal to amplitude-modulate the rf output, when the MODULATION Selector switch is in the AM EXT position. In that mode, the rf output will be turned off until an external modulation signal is applied. A +10 V signal will turn on the rf output to the set level in leveled operation or to the maximum level in unleveled operation. For high speed pulse modulation control, a signal of about +100 V peak is required to drive the ac coupling circuit which applies the input directly to the microwave tube. Input impedance is about 2 K ohms shunted by 100 pf. Pulse modulation response is 0.1 μs for full-range on-off in unleveled operation; 10 μs with solid-state leveling and 20 μs with grid-leveling.
RF SAMPLER INPUT (on Oscillator Plug-in)	Permits connection of a signal from an external sensing coupler and detector to drive the leveling circuits. A detector input of approximately -100 mv, corresponding to rated rf power output, is required for optimum performance. Input impedance is 2800 ohms.
RF OUTPUT Coax or Waveguide Connector	Supplies the Sweep Oscillator output signal.

3.3 REAR PANEL CONTROLS AND CONNECTORS (See Figure 3-2).

A functional description of all rear panel controls and connectors is given in Table 3-3.

Table 3-3. Description of Rear Panel Controls and Connectors

Control or Indicator	Function
REMOTE POWER LEVEL Banana Jacks	Permits connection of an external 1 K potentiometer to provide remote power level control during leveled operation. (See Paragraphs 3.10.3 and 3.12.4 for details.)
REMOTE FREQ 4-Terminal Connector	Permits connection of an external 1 K potentiometer in a shielded circuit to provide remote frequency control. (See Paragraph 3.11.2 for details.)
BLANKING RELAY CONTACT OUTPUT Banana Jacks	Provides S. P. D. T. relay contact operation during sweep retrace on the two slowest sweep ranges. Both normally-open (N.O.) and normally-closed (N.C.) contacts are available to permit use for recorder pen lift control, etc. The contacts have a maximum capacity of 1 amp.
ON OFF BLANKING Snap Switch	When in OFF position, keeps the blanking relay (described above) de-energized. When in ON position, allows the blanking relay to be energized during sweep retrace.
FREQUENCY STABILIZING INPUT (on Oscillator Plug-in with BWO tube)	Permits connection of a signal from an external discriminator for frequency- or phase-locking the oscillator output at any desired single frequency. The input should not exceed ± 50 V (+ increases frequency). Input impedance is 10 K ohms. (See Paragraph 3.11.3 for details).

3.4 INSTRUMENT TURN-ON PROCEDURE

a. Check that the line cord is plugged in and properly grounded.
b. Check that the desired plug-in unit has been inserted and locked into position in the plug-in opening in the Model 650, and that the frequency dial plate for that plug-in has been removed from its storage compartment in the plug-in and placed in the calibrated position on the panel, as described in Paragraph 2-6.
c. Turn the FREQUENCY Mode Selector switch to OFF.
d. Turn the POWER toggle switch ON.
e. The POWER ON indicator light should glow immediately. If not, check that the plug-in LOCK knob is properly tightened (it actuates an interlock switch).
f. After about 60 seconds, the HIGH VOLTAGE ON light should glow. The instrument is now ready to provide rf output.
g. Turn to the appropriate paragraph(s) below for the control settings and operating procedures for the desired mode of operation.

CAUTION

When changing Plug-in units, turn the POWER switch off and wait 15 seconds before removing the installed Plug-in unit and inserting the other Plug-in unit, to permit decay of the power supply voltages. Then repeat the above turn-on procedure.

NOTE

The FREQUENCY Mode Selector switch removes the rf output when placed in the OFF position, and keeps the instrument in "standby" condition ready for instant use. Thus, the FREQUENCY Mode Selector switch may be placed in the OFF position until output connections are completed, and during "warmup" periods and other downtime. RF OUTPUT is instantly restored when the FREQUENCY Mode Selector switch is set to any other position.

3.5 OPERATING PROCEDURES FOR SWEPT-FREQUENCY OUTPUT MODES.

3.5.1 GENERAL. The Model 650 can be operated in either swept-frequency or fixed frequency modes of operation. In swept-frequency operation, the sweep can be either automatically or manually controlled, using panel controls or remote control signals. There are two automatic sweep modes: the broadband ($F_1 \rightarrow F_2$) sweep and the narrow-band ($F_0 \pm \Delta F$) symmetrical sweep. In many situations the broadband sweep will be used for quick-look testing over a large portion of the band, and the narrow-band sweep can be used to examine areas of interest discovered in the broadband sweep. The ALFRED Model 650 Series is unique in that the two sweep modes are set with independent controls, so that operation can be switched quickly from one to the other by simply switching the FREQUENCY Mode Selector switch.

There are two manual sweep modes: one in which the selected "single" frequency is swept by manually turning its frequency control knob, and another in which the MANUAL SWEEP control drives the sweep between preset limits.

3.5.2 BROADBAND ($F_1 \rightarrow F_2$) SWEEP OPERATION

3.5.2.1 BASIC DATA. In the broadband sweep mode of operation, the frequency can be swept over all or any portion of the frequency range of the unit, as determined by the selected start frequency (F_1) and stop frequency (F_2) points. The sweep is always made in the direction of increasing frequency. The time to sweep from F_1 to F_2 can be varied from 10 milliseconds to 100 seconds. During the forward sweep an auxiliary sweep output voltage varying from 0 to +15 V is available for use in driving the horizontal axis of an oscilloscope or recorder. The sweep can be triggered by several alternate means, and the rf output can be either on or off during the retrace interval (after F_2 is reached and until the next sweep is triggered). Various modulation options and marker pips are available. Auxiliary blanking signals are available during retrace. The SWEEP light glows for the duration of each $F_1 \rightarrow F_2$ forward sweep.

3.5.2.2 DETAILED PROCEDURE. For broadband sweep operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$.
RETRACE (red) switch to ON or OFF depending on whether rf output is wanted on or off during the retrace interval between sweeps.
FREQUENCY F_1 Dial Control to desired sweep start frequency.
FREQUENCY F_2 Dial Control to desired sweep stop frequency.
Set SWEEP TIME and SWEEP TRIGGER controls to obtain desired sweep response (see Paragraphs 3.7 and 3.8).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP sawtooth and BLANKING signals, see Paragraph 3.15.

NOTE: To examine a point of interest observed during the broadband sweep mode, adjust the F_0 control (which operates a marker during $F_1 \rightarrow F_2$ sweep) until its marker is on the point of interest; then switch the FREQUENCY Mode Selector to $F_0 \pm \Delta F$ and the narrow-band sweep (see Paragraph 3.5.3) will automatically be centered on that point.

3.5.3 NARROW-BAND ($F_0 \pm \Delta F$) SYMMETRICAL OPERATION.

3.5.3.1 BASIC DATA. In this mode, a center frequency (F_0) can be set anywhere in the band and the rf is swept symmetrically about this point with a maximum sweep range of ± 5% of the full frequency range. The center frequency can be moved during operation by turning the F_0 control, to allow quick adjustment of the area being examined to any desired point. Sweep time control settings set the time to sweep from $-\Delta F$ to $+\Delta F$. Other control arrangements and auxiliary output signals are essentially the same as in the broadband sweep, except that only two markers are available because the F_0 control (which positions a marker in $F_1 \rightarrow F_2$ sweep) is used to control the sweep center frequency. The same 0 to +15 V dc sweep output is supplied to drive a recorder or scope horizontal axis during the sweep from $-\Delta F$ to $+\Delta F$. Thus, when the operating mode is switched from broadband to narrow-band sweep, this output permits automatic expansion of the display to fill the same horizontal length. The SWEEP light glows for the duration of each forward sweep from $F_0 - \Delta F$ to $F_0 + \Delta F$.

3.5.3.2 DETAILED PROCEDURE. For narrow-band symmetrical sweep operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$.
RETRACE (red) switch to ON or OFF depending on whether

rf output is wanted on or off during the retrace interval between sweeps.
FREQUENCY F_0 Dial Control Knob to desired center frequency of narrow-band sweep.
ΔF AMPLITUDE Control to a position corresponding to the desired sweep frequency range, up to a maximum of ± 5% of the full instrument band. (See NOTE below.)
Set SWEEP TIME and SWEEP TRIGGER Controls to obtain desired sweep response (see Paragraph 3.7 and 3.8).
If markers are desired - see Paragraph 3-13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP sawtooth and BLANKING signals, see Paragraph 3.15.

NOTE: To change the center frequency or sweep width, the F_0 and ΔF controls can be adjusted at any time. ΔF remains constant as F_0 is adjusted, unless the ΔF AMPLITUDE control is also adjusted. To calibrate the sweep width obtained with the ΔF AMPLITUDE control, set the M_1 and M_2 markers to the desired sweep limits above and below F_0. Then turn the ΔF AMPLITUDE control to the point where the markers appear at the sweep limits. (See Paragraph 3.13.)

3.5.4 MANUAL SWEEP USING MANUAL SWEEP CONTROL.

3.5.4.1 BASIC DATA. In this mode, the rf output can be swept over all or any portion of the full frequency range of the instrument, as determined by the start frequency point (F_1) and the stop frequency point (F_2). The sweep position between these two points is controlled by the position of the MANUAL SWEEP Control, and the sweep may therefore be made in either direction, (or back-and-forth) and at any desired rate. The dc sweep output provided in this mode has the same frequency dependence as in the $F_1 \rightarrow F_2$ automatic sweep, varying linearly from 0 to +15 V as the sweep is manually driven between F_1 and F_2. This feature makes this mode especially convenient for use with recorder readout, since it permits precise frequency positioning with the same horizontal axis calibration as provided in automatic sweep. While the manual sweep back from F_2 to F_1 can be considered a "retrace," there is no rf blanking available and no auxiliary blanking output during this mode. The sweep time and triggering controls are non-functional in this mode, but markers, modulation, and auxiliary dc sweep output are available.

3.5.4.2 DETAILED PROCEDURE. For manual sweep operation using the MANUAL SWEEP Control, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
SINGLE Frequency Selector to F_2.
FREQUENCY F_1 Dial Control Knob to desired low-frequency end of sweep.
FREQUENCY F_2 Dial Control Knob to desired high-frequency end of sweep.
MANUAL SWEEP (red) Control: turn as desired to electronically sweep the signal between F_1 (at its counterclockwise limit) and F_2 (at its switched clockwise limit).
If markers are desired - see Paragraph 3.13.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output is to be unleveled - turn RF OUTPUT switch to UNLEVELED.
If it is desired to use optional OUTPUT SWEEP dc signal, see Paragraph 3.15.

NOTE: If the MANUAL SWEEP Control is turned fully CW to its switched F_2 position, the output frequency can then be swept and monitored on the frequency dial by turning the FREQUENCY F_2 Control Knob. To monitor specific frequency points when the MANUAL SWEEP control is operating the sweep (with no indication on the frequency dial), the markers can be utilized.

3.5.5 MANUAL SWEEP USING FREQUENCY CONTROL KNOBS.

3.5.5.1 BASIC DATA. In this mode, the rf output can be swept over all or any part of the full frequency range without using preset start and stop points, and controlled by any one of the FREQUENCY or MARKERS controls. The instantaneous frequency output can thus be monitored on the frequency dial. The other operating features are the same as in the manual sweep mode using the MANUAL SWEEP control, except that markers are available only when the FREQUENCY F_2 Control is used to control the sweep.

3.5.5.2 DETAILED PROCEDURE. For manual sweep operation using the FREQUENCY Control Knobs, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
SINGLE Frequency Selector to any position (corresponding to the Control Knob to be used for sweeping the output signal).
FREQUENCY or MARKERS Control Knob selected by the above setting of the SINGLE Frequency Selector: turn as desired to sweep the rf output signal in any desired manner; output frequency is indicated by the corresponding indicator bar on the frequency dial.
MANUAL SWEEP (red) Control to its switched F_2 position (not required unless F_2 is used).
If modulation is desired - see Paragraph 3.9.
If modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output leveling is not desired - turn RF OUTPUT switch to UNLEVELED.
If markers are desired (F_2 Control Mode only) - see Paragraph 3.13.
If markers are not desired in F_2 Control Mode - turn MARKER AMPLITUDE Control of OFF limit of rotation.
If it is desired to use optional OUTPUT SWEEP signal, see Paragraph 3.15.

NOTE: When F_1, F_2, M_1 or M_2 Control Knobs are selected for sweep control, the unused knob which shares the same dial indicator slot should be turned to the corresponding band edge so as not to interfere with the Control Knob and indicator bar being used.

3.6 OPERATING PROCEDURES FOR SINGLE-FREQUENCY OUTPUT MODE.

3.6.1 GENERAL DATA. The instrument can be used to generate fixed (single) frequency rf output that is either unmodulated (CW) or modulated. The output frequency is determined by any

one of the five frequency indicators (F_0, F_1, F_2, M_1, or M_2) as selected by a front panel switch; and the frequency indicators are continuously adjustable to provide any desired frequencies within the instrument range. The frequencies can be changed and adjusted as desired during operation. For fixed-frequency operation where only one single frequency is required, the choice of which Control Knob to select is arbitrary. In many cases, however, it will be convenient to be able to switch quickly between up to five pre-selected frequencies which are related to channel limits or other points of interest. In that case, by setting the five frequency indicators to the different frequencies in the order $F_1 - M_1 - F_0 - M_2 - F_2$, it will be possible to quickly select them in sequence by turning the SINGLE Frequency Selector switch.

NOTE: If frequency modulation is to be used with single-frequency operation, disregard the following procedure and instead follow the procedure of Paragraph 3.5.3.1 for $F_0 \pm \Delta F$ sweep. Turn the ΔF AMPLITUDE control fully CCW to its OFF limit of rotation, and the F_0 control to the desired single frequency. This procedure must be used because the FREQUENCY Mode Selector switch must be set to a SWEEP position to eliminate internal ac feedback which would interfere with fm modulation. External frequency stabilization can be used with the following single-frequency operating procedure (see Paragraph 3.11.3.1 for details).

3.6.2 DETAILED PROCEDURE. For fixed-frequency operation, turn the instrument on as described in Paragraph 3.4 and make control settings as follows:

FREQUENCY Mode Selector to SINGLE.
FREQUENCY and MARKERS Control Knobs: turn one or more controls as desired to select one or more output frequencies for selection by the SINGLE Frequency Selector switch. If several frequencies are desired, the mechanical limitation of the frequency dial will require F_2 to be above F_1, and M_2 to be above M_1. If it is desired to switch between frequencies in ascending or descending order, the indicators used for the various frequencies should be chosen in the same sequence as the positions of the SINGLE Frequency Selector ($F_1 - M_1 - F_0 - M_2 - F_2$).
SINGLE Frequency Selector to the position corresponding to the dial indicator set at the desired rf output frequency.
MARKER AMPLITUDE Control to its OFF limit of rotation (not required unless F_2 is used).
MANUAL SWEEP (red) Control to its switched F_2 position (not required unless F_2 is used).
If amplitude modulation is desired - see Paragraph 3.9.
If amplitude modulation is not desired - turn MODULATION control to AM OFF.
If output leveling is desired - see Paragraph 3.12.
If output leveling is not desired - turn RF OUTPUT switch to UNLEVELED.
If output frequency stabilization using an external frequency or phase-locking device is desired - see Paragraph 3.11.3.1.

NOTE: Any or all of the frequencies can be adjusted at any time during use by turning the Control Knobs. The output frequency can be "swept" by adjusting the Control Knob for the output signal in use.

3.7 SELECTION OF SWEEP TIME.

The SWEEP TIME Selector switch controls the time required for each sweep to progress from the start frequency (F_1 or $F_0 - \Delta F$, depending on mode) to the stop frequency (F_2 or $F_0 + \Delta F$). It provides four calibrated positions when the red VARIABLE control is tuned to its clockwise CALIBRATED end position. When the VARIABLE control is turned counterclockwise out of the CALIBRATED position, it slows the sweep by a variable amount which increases to 10:1 at the extreme counterclockwise end. Thus, a continuously adjustable sweep time range from .01 sec. to 100 sec. is available by proper adjustment of the SWEEP TIME and VARIABLE controls.

The .01 and .1 second ranges are most convenient for oscilloscope display; the 1.0 second range for small strip chart recorder readout; and the 10 second range for X-Y recorder readout. The 100 second sweep can be used for special applications such as measurement of output power or modulation characteristics with external meters.

3.8 SELECTION OF SWEEP TRIGGER MODE.

The SWEEP TRIGGER Selector switch positions provide four types of sweep triggering: automatically recurring sweeps triggered either from the LINE or in a FREE RUN mode; MANUAL triggering; or EXTERNAL control of triggering.

Automatically recurring sweeps are most convenient for oscilloscope display. The LINE triggering mode is useful in systems where display or other equipment is line-synchronized; otherwise the FREE RUN mode can be used.

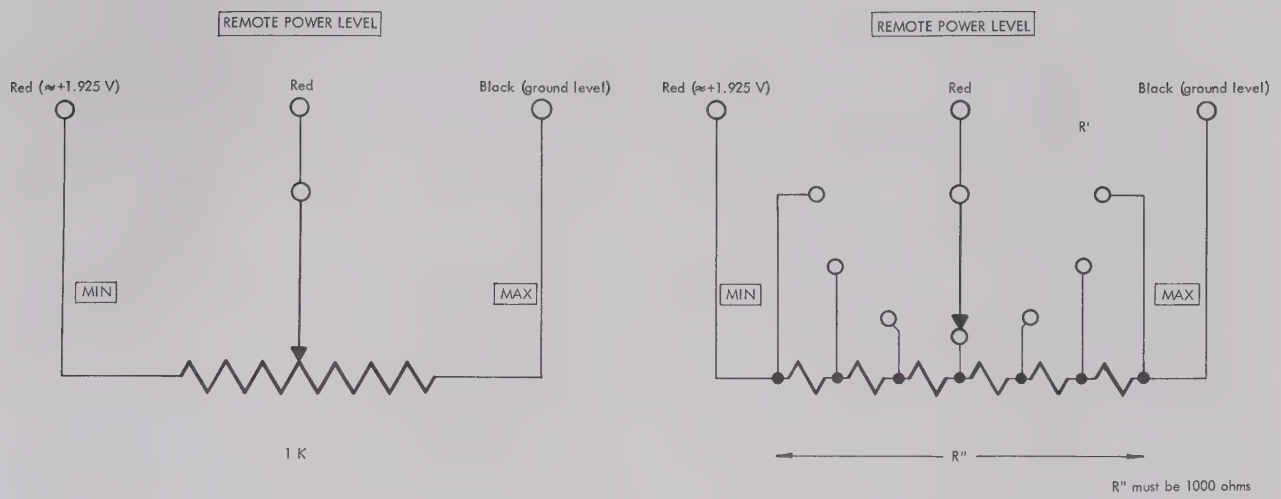
Non-recurring sweep is most convenient for recorder readout, so that just one trace can be triggered after the readout equipment is set-up and calibrated. In the MANUAL switch position, one sweep is triggered each time the red PUSH button is pressed.

The EXTERNAL triggering mode can be used for either automatically recurring or one-shot non-recurring sweeps synchronized with external equipment. In this mode, a signal of at least +5 V with a duration of at least 10 microseconds applied to the EXTERNAL INPUT connector will trigger a sweep (provided that the previous sweep has been completed). Trigger signals received prior to completion of the previous sweep will be disregarded. Thus a pulse train with any convenient PRF can be used for triggering and synchronizing recurrent sweeps with external equipment if each individual pulse meets the above specifications. For triggering individual sweeps, a single pulse or a positive step-voltage of at least +5 V can be used. Input impedance is greater than 10 K ohms.

3.9 MODULATING THE RF OUTPUT.

The rf output can be either amplitude modulated (using an external signal or the internal square wave) or frequency modulated (using external signals). Modulation of either type can be used in single-frequency and swept modes of operation, and can be obtained with low-level signal voltages which need not exceed 15 V. The front panel MODULATION switch allows selection of either external (AM EXT) or internal (SQ WAVE) amplitude modulation (ON-OFF type only), or no amplitude modulation (AM OFF). In the AM OFF position, (or either of the other positions if combined modulation is desired), frequency modulation can be obtained by applying a suitable signal to the front panel FM INPUT connector or the rear panel REMOTE FREQ connector, and variable-level amplitude modulation can be obtained by connecting a variable resistance to the REMOTE POWER LEVEL jacks.

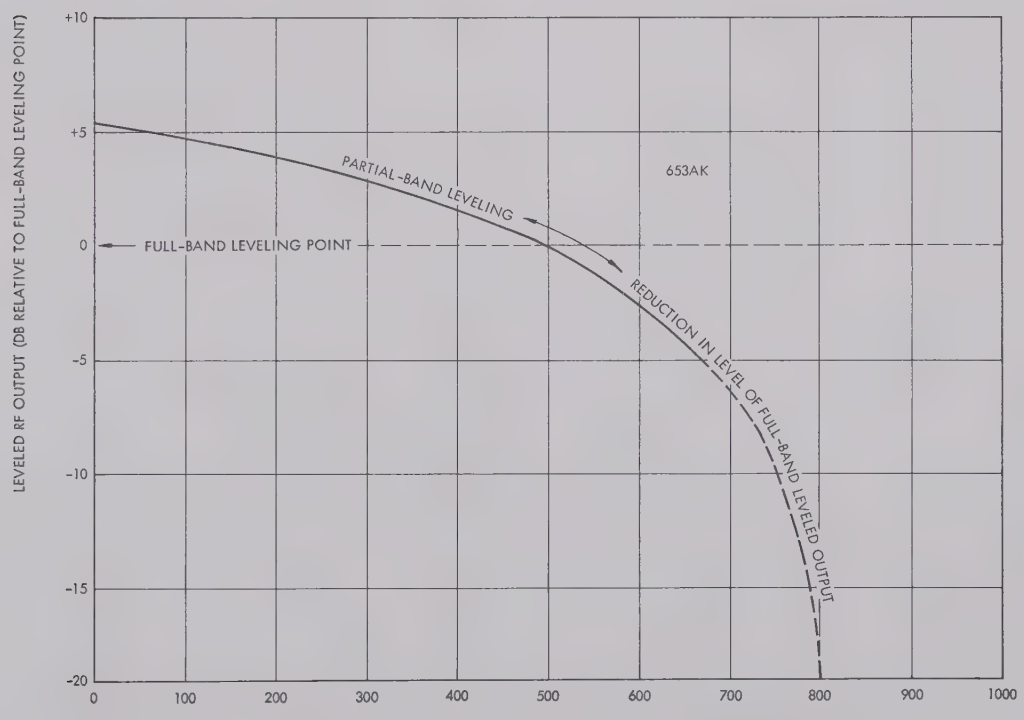
Each of these modulation modes is discussed separately below. The amplitude modulation modes are discussed under Paragraph



A. Circuit Using External Potentiometer

B. Circuit Using Switched Resistive Network

NOTE: ON BWO UNITS, THE OUTPUT LEVEL DECREASES TO THE FULL-BAND LEVELING POINT AND THEN AT LEAST AN ADDITIONAL 5 DB AS THE WIPER OF THE 1 K POTENTIOMETER IS MOVED FROM THE "MAX" TO "MIN" LIMIT. A SWITCHED RESISTOR NETWORK PROVIDES SIMILAR RESPONSE. ON SOME UNITS, THE CONTROL RANGE IS GREATER THAN 6 DB. THE RED POWER LEVEL CONTROL ON THE FRONT PANEL MUST BE TURNED FULLY CLOCKWISE TO ENABLE THE MAXIMUM CONTROL RANGE WITH THE REMOTE POWER LEVEL JACKS. THE FRONT PANEL CONTROL CAN BE USED TO REDUCE THE OUTPUT TO THE LEVELING POINT FOR THE SWEEP RANGE USED. THEN THE REDUCED-RANGE REMOTE ADJUSTMENT WILL BE UNIFORMLY BELOW THE LEVELED VALUE. VTM UNITS WITH SOLID-STATE LEVELING HAVE SIMILAR RESPONSE. ON VTM UNITS WITHOUT SOLID-STATE LEVELING, REMOTE POWER LEVEL CONTROL WILL REDUCE THE OUTPUT LEVEL TO THE FULL-BAND LEVELING POINT, AND UP TO 1 DB ADDITIONAL.



NOTE: FOR ACCURATE CONTROL OF A PARTICULAR PLUG-IN UNIT, A SIMILAR INDIVIDUAL CURVE SHOULD BE PLOTTED FOR THAT UNIT.

C. Graph Of Typical Response To Resistance Connected To REMOTE POWER LEVEL Jacks

FIGURE 3-3. REAR PANEL CONNECTIONS FOR EXTERNAL POWER LEVEL PROGRAMMING OR AMPLITUDE MODULATION WITH LEVELED OUTPUT

3.10, and frequency modulation under Paragraph 3.11.

3.10 AMPLITUDE MODULATION.

3.10.1 INTERNAL (SQUARE WAVE) AMPLITUDE MODULATION. This type of modulation is convenient for use in measurement systems which have an audio-frequency measurement circuit, such as most reflectometer and ratio meter set-ups. For such applications, turn the MODULATION Selector to SQ WAVE and adjust the red Frequency Vernier Control to its mid-range position to obtain an output modulation frequency of about 1000 cps (the standard for most systems). The Frequency Vernier Control permits varying the modulation frequency from about 800 to 1200 cps when turned clockwise through its range of rotation. This can be used to set the modulating frequency for optimum response with any measurement system. The stability of the square wave frequency is better than 0.2% per hour under a fairly even temperature environment.

With internal square-wave modulation, 100% modulation is obtained, so that the rf output is either full-on (to pre-set level where applicable) or off during each half-cycle of the square wave. During the off portion of the square wave, the tube is biased beyond beam cut-off, so that the ON to OFF ratio is infinite. In the LEVELED condition the rise and fall time is less than 20 μs between the 10% and 90% power points; UNLEVELED response is even faster. The symmetry ratio between the ON and OFF portions of the square wave is between .95 and 1.05. The use of square wave modulation does not shift the rf output frequency, nor does it degrade the excellent rf output frequency stability in single-frequency modes.

3.10.2 EXTERNAL "ON-OFF" AMPLITUDE MODULATION. This type of modulation extends the versatility of the instrument to permit many special applications ranging from simple external on-off rf control by an external source to high-speed pulse modulation. When the MODULATION selector is turned to the AM EXT position, the rf output is turned off until a positive signal is applied to the AM EXT INPUT connector. A +10 V signal turns the microwave tube ON, and when the voltage drops below +6 V the tube is turned off. This modulation is of the ON-OFF type and the on to off ratio is infinite. (This EXT AM mode is intended only for ON-OFF type modulation control since it operates digital control circuits. If variable-amplitude control is desired, it should be obtained by means of signals applied to the REMOTE POWER LEVEL jacks, as discussed in Paragraph 3.10.3.

The rise and fall time, when in the leveled condition, is better than 10 μs with solid-state leveling and 20 μs with grid leveling. When in the unleveled condition, rise and fall time is ≈ 1 μs. For high-speed pulsed rf operation, with the output in the unleveled condition, it is possible to obtain rise and fall times of .05 μs if a pulse generator is used to drive the AM EXT connector. The pulse generator should have a 50-ohm output impedance and should be capable of supplying at least +100 V (to drive the ac coupling circuit connecting directly to the microwave tube) with a rise and fall time better than .02 μs. Some Model 650 Plug-in units require less than the +100 V as specified above. (For the exact value, check the Instruction Manual for the particular plug-in involved.) The input impedance of the EXT AM input is approximately 2 K Ω shunted by 100 pf.

3.10.3 EXTERNAL VARIABLE-LEVEL AMPLITUDE MODULATION. (See Figure 3-3.) This mode can be used to obtain amplitude modulation with any desired modulation factor up to an on-off ratio of 10 db or greater. Since this mode makes use of the leveling circuits, the best pulse response rise and fall time is about 10 μs. This type of modulation is available while operating with the rf output in the leveled condition, with either internal or external sampling. With leveled rf output, variable-level amplitude modulation (or remote output level programming) is available through resistive network connections to the REMOTE POWER LEVEL banana jacks in the rear. The procedure is given below:

For this mode, the controls must be set for internal or external leveling operation as described in Paragraph 3.12, and the red POWER LEVEL control must be turned fully clockwise. Then modulation of the output level can be obtained by connecting a 1 K potentiometer or an equivalent resistive network between the three REMOTE POWER LEVEL banana jacks on the rear panel, as shown in Figure 3-3. As the center red terminal connection is adjusted across 1 K resistance between the MAX and MIN jacks, the power level will decrease to the full-band leveling point and then at least 5 db below that level. An overall reduction of maximum power level in this mode can be obtained by turning the front panel POWER LEVEL control, CCW; but when this control is turned out of the fully clockwise position, the control range available from the REMOTE POWER LEVEL jacks will be reduced. While the main purpose of these terminals is to permit remote control of the output level, rather than amplitude modulation, a motor-driven potentiometer or switched network can be used to apply modulation through this circuit. Read Paragraph 3.12.4 for additional data.

3.11 FREQUENCY MODULATION.

The Model 650 Series Sweep Oscillators provide three modes of frequency modulation and/or external frequency control, each of which has its own input jack(s) and a specific application. The separate jacks are the FM INPUT front panel jack, and the REMOTE FREQ and FREQUENCY STABILIZING INPUT rear panel jacks. (The FREQUENCY STABILIZING INPUT jack is provided on BWO plug-in units only. It is located on the rear of the plug-in unit, and is accessible through an opening in the Model 650 rear panel.)

For most fm modulation applications, the FREQUENCY Mode Selector switch must be in a SWEEP position to eliminate internal ac feedback which would tend to oppose frequency variations. Single-frequency operation for application of fm can be obtained by leaving the sweep untriggered and/or setting ΔF to zero in the $F_0 \pm \Delta F$ swept mode.

The FM INPUT jack is used for frequency-modulating or sweeping the rf output signal by means of applied signal voltages. The REMOTE FREQ jack is used to permit remote adjustment or programming of the rf output frequency by means of an adjustable potentiometer or resistive network. The FREQUENCY STABILIZING jack is used to obtain ultra-stable single-frequency output by coupling in feedback error signals from a frequency discriminator or phase detector. Each of these modes is discussed separately below.

3.11.1 VOLTAGE-CONTROLLED FM USING THE FM INPUT JACK (See Figures 3-4, 3-5, and 3-6).

3.11.1.1 GENERAL DATA. With either swept or single-frequency output, the rf signal can be frequency modulated by applying a signal to the FM INPUT jack. The frequency of the applied modulating signal can be from dc to 10 Kc. With frequency modulation, the instantaneous rf output frequency will be the sum of the frequency called for by the panel controls,

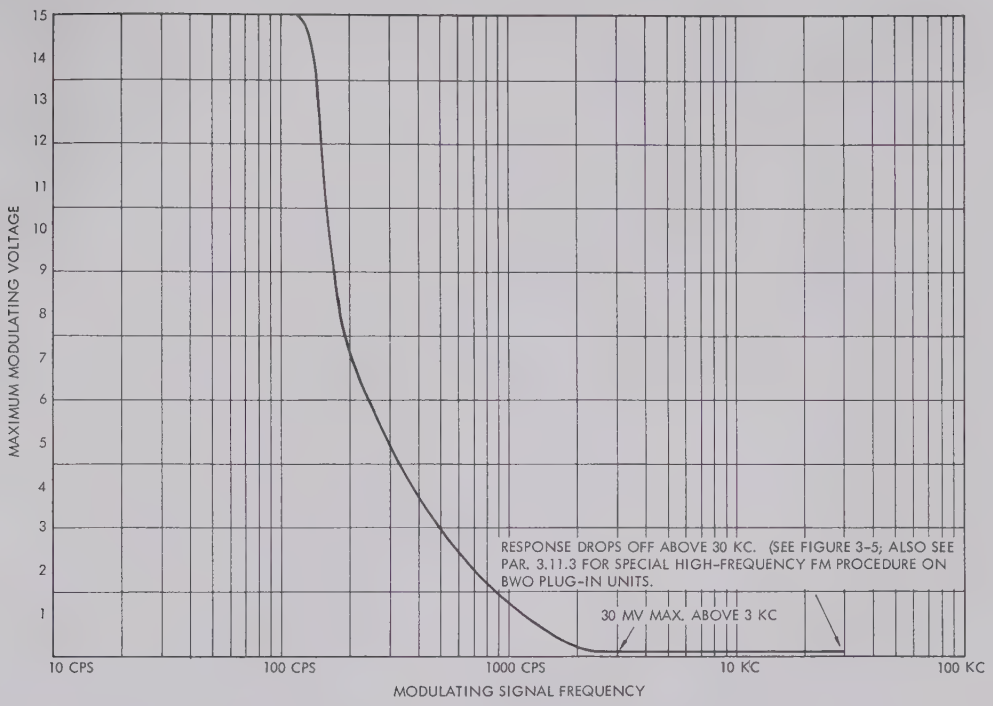


FIGURE 3-4. MAXIMUM ALLOWABLE MODULATING VOLTAGE VS MODULATING SIGNAL FREQUENCY FOR LARGE-SIGNAL FM MODULATION AT FM INPUT JACK

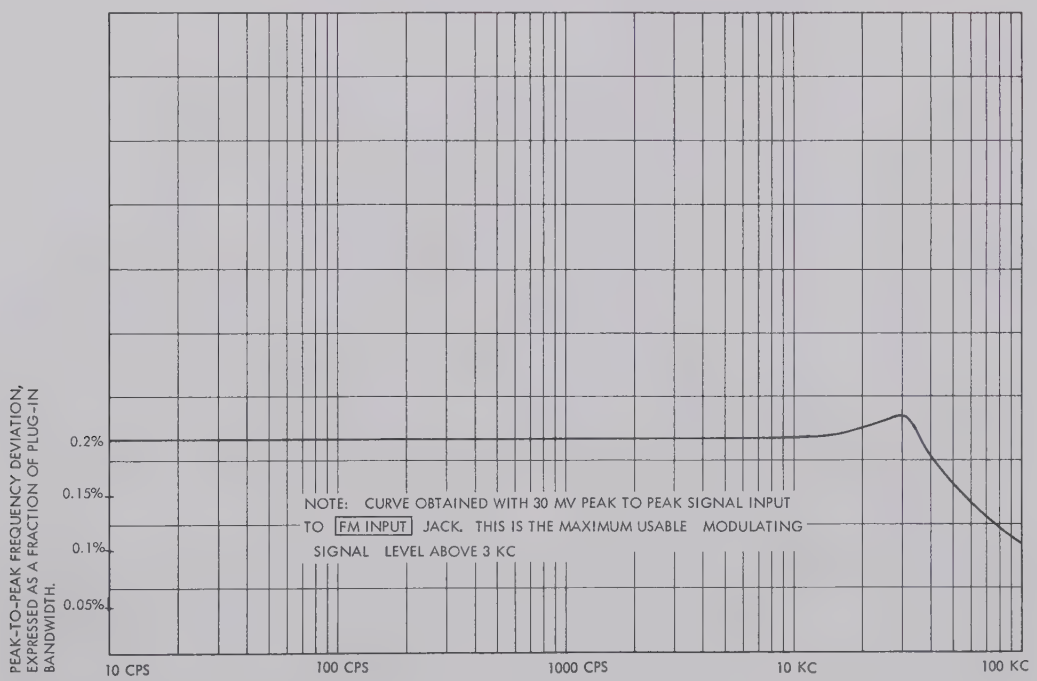

PEAK-TO-PEAK FREQUENCY DEVIATION, EXPRESSED AS A FRACTION OF PLUG-IN BANDWIDTH.
0.2%
0.15%
0.1%
0.05%
NOTE: CURVE OBTAINED WITH 30 MV PEAK TO PEAK SIGNAL INPUT TO FM INPUT JACK. THIS IS THE MAXIMUM USABLE MODULATING SIGNAL LEVEL ABOVE 3 KC
10 CPS
100 CPS
1000 CPS
10 KC
100 KC

FIGURE 3-5. MODULATION RESPONSE VS MODULATING SIGNAL FREQUENCY FOR SMALL-SIGNAL FM MODULATION AT FM INPUT JACK

and the up-scale or down-scale adjustment called for by the applied modulation. For single-frequency operation, the $F_0 \pm \Delta F$ swept mode is used with ΔF set to zero and F_0 at the desired frequency. With the F_0 control set at the low end of the band in single-frequency operation, a signal of +15 V applied to the FM INPUT jack will drive the output frequency to the high end.

Operation is linear, with an output signal of less than +15 V producing a proportional fraction of a full-range upscale frequency swing. Modulating signals of negative polarity can similarly be used to drive the output frequency below that set by the panel controls. The amount of deviation obtainable by application of a particular modulating voltage is thus proportional to the bandwidth between the frequency limits of the plug-in. It is equal to the voltage expressed as a fraction of 15 V times the plug-in bandwidth. Maximum deviation obtainable through use of the FM INPUT jack is limited by both the frequency of the modulating signal (which determines how fast the rf must be deviated) and the rf output frequency range of the plug-in (which determines how much deviation a given voltage produces). The relationship of permissible modulating voltage to the modulating signal frequency is shown in Figures 3-4, 3-5, and 3-6. Higher-frequency response (which is also non-linear) can be obtained in BWO plug-in units by applying modulation directly to the helix as described in Paragraph 3.11.3.

CAUTION: The rf output can never be driven beyond the band' edge frequencies shown on the plug-in panel without distortion, and application of excess voltage in an attempt to drive the frequency beyond the high limit of the band may damage the microwave tube.

NOTE: Discussions in this section are in terms of the nominal 0 V to +15 V control range. Due to mechanical limitations in the dial mechanism, the instrument is factory-calibrated to produce the full frequency output range in response to a slightly reduced voltage range, typically + 0.15 V to +14.75 V corresponding to the range between 0 and 100 on the dial logging scale. Where absolute accuracy is required in remote control applications, the exact FM INPUT voltage values corresponding to the full-range swing should be determined by actual measurement and substituted in the equations. In most cases, the use of 0 and +15 V will produce an error of less than 1%.

3.11.1.2 FREQUENCY-MODULATING A SINGLE-FREQUENCY OUTPUT. To frequency-modulate a single-frequency rf output or to externally drive a swept-frequency output from any preset starting frequency, proceed as follows:

a. Make the following switch settings:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$.
RETRACE switch to ON.
ΔF AMPLITUDE Control to OFF limit of rotation.
SWEEP TRIGGER Selector to MANUAL (so that no internal sweep is triggered; do not push the PUSH button).
FREQUENCY F_0 Control Knob to set the desired starting frequency for fm or externally driven sweep.
Unless simultaneous amplitude modulation is desired - turn MODULATION control to AM OFF.
If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling is desired - see Paragraph 3.12.

b. Calculate the signal amplitude to be applied to the FM INPUT jack to achieve the desired frequency modulation, using the following equations:

1) Instantaneous rf output frequency increment, Δf, due to applied modulating voltage:

$$\Delta f = \frac{\text{instantaneous modulating voltage}}{+15} \times \boxed{\begin{matrix}\text{instrument}\\ \text{frequency}\\ \text{range in Gc}\end{matrix}}$$

where the instrument frequency range in Gc = (highest dial frequency)-(lowest dial frequency). Note that Δf can be positive or negative, depending on the polarity of the modulating signal.

2) Instantaneous output frequency, F_{output}, due to the combination of internal and external signals:

$F_{output} = \Delta f$ + indicated single-frequency dial setting.
or
$\Delta f = F_{output}$ - indicated single-frequency dial setting.

NOTE: To sweep the entire band, set the F_0 frequency indicator to the low end of the band and apply a 0 to +15 V sweep at the FM INPUT jack. If the dial-set output frequency is above the low end of the band, Δf must be reduced accordingly by reducing the modulation voltage, to keep F_{output} within the usable band.

Example A

Conditions:
- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Indicated frequency = 4.7 Gc (F_0 set to 4.7 Gc)
- Instantaneous modulating voltage = + 5 volts

Calculations:
1) Instantaneous frequency increment, Δf: $\Delta f = 5/15 \times 4$ Gc = $1/3 \times 4$ Gc = 1.33 Gc
2) Instantaneous output frequency = 1.33 Gc + 4.7 Gc = 6.03 Gc

Example B

Conditions:
- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Indicated frequency = 4.7 Gc (F_0 set to 4.7 Gc)
- Instantaneous modulating voltage = -5 V

Calculations:
1) Instantaneous frequency increment, Δf: $\Delta f = -5/15 \times 4$ Gc = $-1/3 \times 4$ Gc = -1.33 Gc
2) Instantaneous output frequency = -1.33 Gc + 4.7 Gc = 3.37 Gc

Thus, it can be seen that a +5 V signal applied to the fm input jack produces an instantaneous frequency of 6.03 Gc, which falls within the frequency limits of the unit (4 to 8 Gc) but the instantaneous frequency produced by the -5 V signal is below the minimum frequency, and will produce distorted output.

Example C

Conditions:
- Plug-in unit range = 8 to 12.4 Gc; therefore frequency range = (12.4 - 8.0) Gc = 4.4 Gc
- Desired starting frequency for externally driven sweep = 9.3 Gc (set F_0 to 9.3 Gc).
- Desired sweep top frequency = 11.7 Gc

Calculations:
1) Determine the required maximum output frequency increment, Δf, to be produced by the modulating signal to drive from the start frequency to the top frequency, using the F_{output} equation: Δf = (11.7 - 9.3) Gc = 2.4 Gc

2) Determine the required maximum modulating signal level to achieve the desired sweep frequency increment, using the Δf equation:

$$2.4\ Gc = \frac{V_{mod}}{15} \times 4.4\ Gc$$

(simplify by dividing both sides by 4.4 Gc and multiplying both sides by 15)

$$15 \times \frac{2.4}{4.4} = V\ mod = +8.2\ volts$$

Thus, to obtain a linear sweep, a signal varying from 0 to +8.2 volts would be required.

Example D

Conditions:
- Plug-in unit range = 1 to 2 Gc; therefore, frequency range = (2 - 1) Gc = 1 Gc
- Indicated frequency = 1.5 Gc (F_0 set to 1.5 Gc)
- Desired shifted output frequency = 1.05 Gc

Calculations:

1) Determine the output frequency increment, Δf, to obtain the desired frequency-shift performance, using the F_{output} equation:

$\Delta f = (1.05 - 1.5)\ Gc = -0.45\ Gc$

Note that the minus sign denotes a frequency decrease.

2) Determine the required modulating signal voltage to achieve the desired frequency shift, using the Δf equation:

$$\Delta f = \frac{V_{mod}}{15} \times 1\ Gc = -0.45\ Gc$$

$$V_{mod} = -0.45 \times 15 = -6.75\ volts$$

Example E

Conditions:
- Plug-in unit range = 7 to 12.4 Gc; therefore frequency range = (12.4 - 7) Gc = 5.4 Gc
- Indicated frequency = 10.5 Gc (F_0 set to 10.5 Gc)
- Desired rf deviation: ± 1.5 Gc

NOTE: A cursory check shows that this is within the frequency range of the instrument, since the maximum and minimum frequencies produced by the deviation are 9 Gc and 12 Gc.

Calculations:

1) Determine the required peak-to-peak frequency deviation, Δf: $\Delta f = 2 \times 1.5\ Gc = 3.0\ Gc$

2) Determine the required peak-to-peak signal level for an ac signal to produce the desired deviation, using the Δf equation:

$$3.0\ Gc = \frac{V_{mod}}{15} \times 5.4\ Gc$$

(Simplify)

$$V_{mod} = 15 \times \frac{3.0}{5.4}$$

V_{mod} = 8.33 volts (peak-to-peak).

Therefore an ac signal of ± 4.16 volts amplitude is required.

c. Apply the proper signal calculated in Step b. to the FM INPUT jack.

NOTE: The frequency of the modulating signal must be within the limits given by Figures 3-4, 3-5, and 3-6. The applied voltage must not be sufficient to drive the output frequency outside the range of the plug-in. Violation of either of these rules will produce distorted output.

3.11.1.3 EXTERNALLY DRIVEN FREQUENCY SWEEP. Refer to Paragraph 3.11.1.2 and Figure 3-6.

3.11.1.4 FREQUENCY MODULATION IN SWEPT-FREQUENCY MODES. An externally-driven sweep or single frequency offset can be added to an internal sweep established by the panel controls, using the following procedure:

a. Make the following switch settings:

FREQUENCY Mode Selector to either SWEEP Mode ($F_0 \pm \Delta F$ or $F_1 \rightarrow F_2$).
RETRACE switch to ON.
FREQUENCY F_1, F_2, or F_0 Control Knobs, and Δ F AMPLITUDE Control - set as appropriate for sweep mode selected (see Paragraph 3.5).
If internal sweep is to be synchronized with the modulating signal - set SWEEP TRIGGER Selector to EXTERNAL and apply a suitable external signal in accordance with Paragraph 3.8.
If internal sweep is to be independent of the modulating signal - set SWEEP TRIGGER Selector to FREE RUN, LINE, or MANUAL (see Paragraph 3.8).
SWEEP TIME Control - set for desired sweep response (see Paragraph 3.7).
Unless simultaneous amplitude modulation is desired - turn MODULATION Control to AM OFF.
If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling is desired - see Paragraph 3.12.

b. Calculate the signal amplitude to be applied to the FM INPUT jack to achieve the desired modulation, using the basic equations given above in 3.11.1.2 b. Consider the limiting conditions that will occur at the high-frequency and low-frequency limits of the sweep due to both the internal and external signals. Select modulation voltages that will not drive the rf output outside the frequency range of the plug-in.

Example A

Conditions:
- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Indicated sweep mode and limits: $F_1 \rightarrow F_2$, with F_1 = 4.5 Gc, F_2 = 6.5 Gc
- Desired rf deviation: ± 0.5 Gc

NOTE: This is the greatest available deviation for the above conditions, since the -0.5 Gc swing at the low end of the sweep will drop the output frequency to the 4.0 Gc lower limit of the plug-in.

Calculations:

1) Determine the required peak-to-peak frequency deviation, Δ f:

$\Delta f = 2 \times 0.5\ Gc = 1\ Gc$

2) Determine the required peak-to-peak signal level for an ac signal to produce the desired deviation, using the Δf equation:

$$1\ Gc = \frac{V_{mod}}{15} \times 4\ Gc$$

(simplify by dividing both sides by 4 Gc and multiplying both sides by 15)

$$15 \times \frac{1}{4} = V_{mod}$$

V_{mod} = 3.75 volts (peak-to-peak).

Therefore, an ac signal of ± 1.875 volts amplitude is required.

Example B

Conditions:

- Plug-in unit range = 8 to 12.4 Gc; therefore frequency range = (12.4 - 8.0) Gc = 4.4 Gc
- Indicated sweep mode and limits: $F_0 \pm \Delta F$, with F_0 set at 10.2 Gc and ΔF set to maximum (approximately ± 0.22 Gc)
- Desired external frequency control: Step the narrow-band center frequency F_0 to 9.0 Gc and 11.5 Gc.

  NOTE: A cursory check shows that this is within the frequency range of the instrument, since the over-all minimum and maximum limit frequencies as the output varies from $-\Delta F$ to $+\Delta F$ will be 8.78 Gc and 11.72 Gc.

Calculations:

1) Determine the frequency deviation, Δf, required for each of the center-frequency steps, using the F_{output} equation:

$$\Delta f_1 = (9.0 - 10.2)\ Gc = -1.2\ Gc$$

Note that the minus sign denotes a frequency decrease.

$$\Delta f_2 = (11.5 - 10.2)\ Gc = 1.3\ Gc$$

2) Determine the required modulating signal voltage to achieve each desired frequency shift, using the Δf equation:

$$\Delta f_1 = \frac{V_{mod}}{15} \times 4.4\ Gc = -1.2\ Gc$$

(simplify)

$$V_{mod} = \frac{-1.2}{4.4} \times 15 = -4.099 \text{ volts for } \Delta f_1$$

$$\Delta f_2 = \frac{V_{mod}}{15} \times 4.4\ Gc = 1.3\ Gc$$

(simplify)

$$V_{mod} = \frac{1.3}{4.4} \times 15 = 4.432 \text{ volts for } \Delta f_2$$

c. Apply the proper signal calculated in Step b. to the FM INPUT jack.

NOTE: The frequency of the modulating signal must be within the limits given by Figures 3-4, 3-5, and 3-6. The applied voltage must not be sufficient to drive the output frequency outside the range of the plug-in. Violation of either of these rules will produce distorted output.

3.11.2 REMOTE FREQUENCY PROGRAMMING USING THE REMOTE FREQ JACK (See Figures 3-6 and 3-7). The REMOTE FREQ connector on the rear of the instrument can be used for frequency programming using external resistors. When remote frequency programming is used, the rf output frequency will be the frequency called for by the panel controls, increased by the programmed frequency increment. The response time is the maximum time it will take for the frequency to be within the specified tolerance of frequency and residual fm. The minimum response time can be determined from Figure 3-6, using the right-hand vertical scale.

NOTE: Because frequency-stabilizing ac feedback is supplied internally in the SINGLE position of the FREQUENCY Mode Selector switch, a single frequency obtained through this mode should be used for remote frequency programming if a response time slower than 100 milliseconds is satisfactory. If response to program changes must be faster than 100 milliseconds, the symmetrical sweep mode ($F_0 \pm \Delta F$) should be used, with no sweep trigger applied.

For remote frequency programming, the programming potentiometer or resistors must be connected as shown in Figure 3-7. Proceed as follows:

a. Make the following switch settings:

Frequency Mode Selector (see note above) - If response of 100 milliseconds is satisfactory, set to SINGLE and turn SINGLE Frequency Selector switch to F_0. Otherwise, set to SWEEP $F_0 \pm \Delta F$.
RETRACE switch to ON.
ΔF AMPLITUDE Control to OFF limit of rotation.
SWEEP TRIGGER Selector to MANUAL (so that no internal sweep is triggered; do not push the PUSH button).
FREQUENCY F_0 Control Knob to set the desired starting frequency for fm or externally driven sweep.
Unless simultaneous amplitude modulation is desired - turn MODULATION control to AM OFF.
If simultaneous amplitude modulation is desired - see Paragraph 3.10.
If markers are not desired - turn MARKER AMPLITUDE Control to OFF limit of rotation.
If markers are desired - see Paragraph 3.13.
If output leveling is desired - see Paragraph 3.12.

b. Calculate the potentiometer wiper position or resistor network values required for connection to the REMOTE FREQ jack. Refer to Figure 3-7 and use the following equations:

1) Rf output frequency shift, Δf, due to programming resistors:

$$\Delta f = \frac{R'}{R''} \times \text{instrument frequency range in Gc}$$

where the instrument frequency range in Gc = (highest dial frequency) - (lowest dial frequency)

NOTE: R" must be 1000 ohms.

Example A

Conditions:

- Plug-in unit range = 4 to 8 Gc; therefore frequency range = (8 - 4) Gc = 4 Gc
- Frequency setting = 4.00 Gc (F_0 set to 4.00 Gc)
- R_1 = 427 ohms.

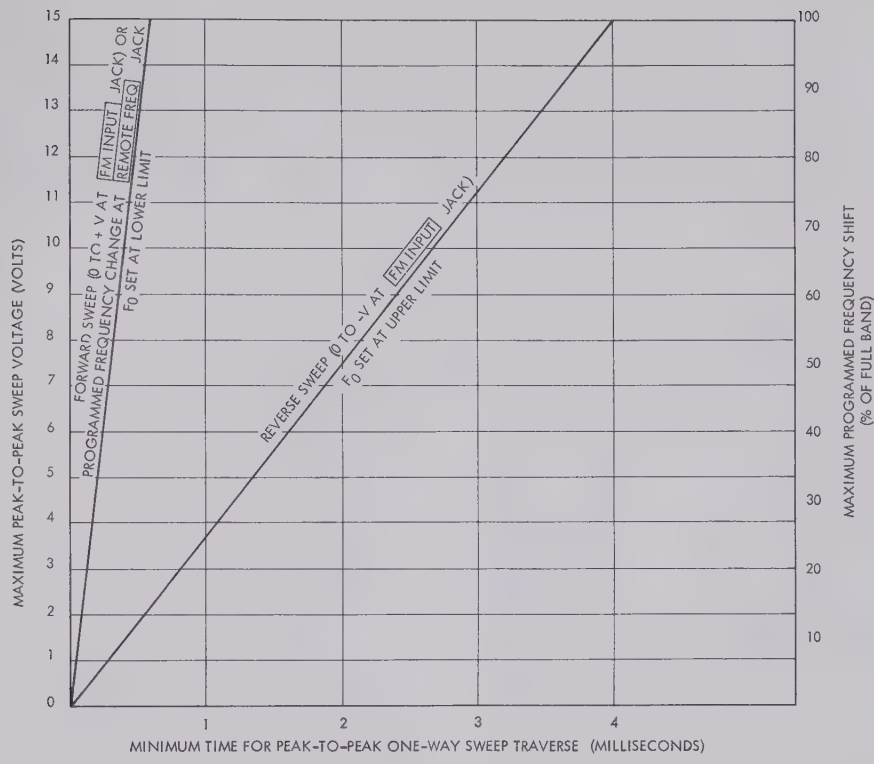
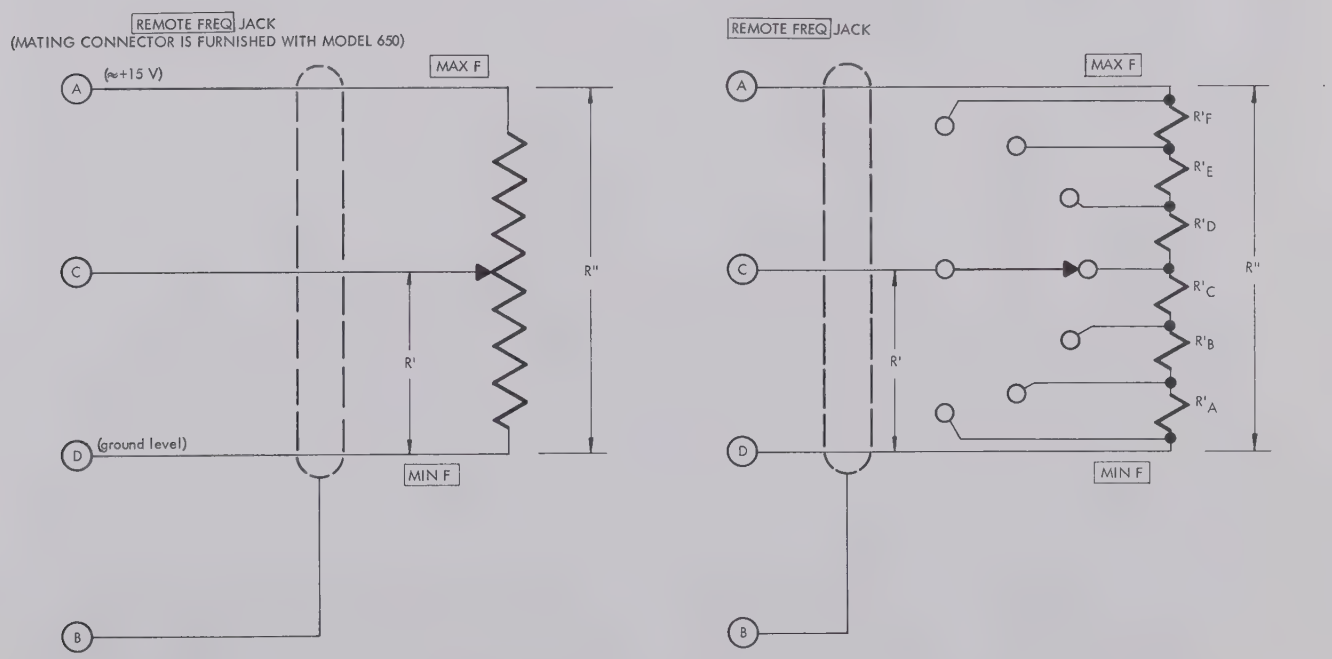

MAXIMUM PEAK-TO-PEAK SWEEP VOLTAGE (VOLTS)
MAXIMUM PROGRAMMED FREQUENCY SHIFT (% OF FULL BAND)
MINIMUM TIME FOR PEAK-TO-PEAK ONE-WAY SWEEP TRAVERSE (MILLISECONDS)
FORWARD SWEEP Ø TO + V AT FM INPUT JACK) OR PROGRAMMED FREQUENCY CHANGE AT REMOTE FREQ JACK
F0 SET AT LOWER LIMIT
REVERSE SWEEP Ø TO -V AT FM INPUT JACK)
F0 SET AT UPPER LIMIT

FIGURE 3-6. MAXIMUM FREQUENCY-SHIFT RATE FOR EXTERNALLY-DRIVEN SWEEP OR EXTERNAL FREQUENCY PROGRAMMING



NOTES:

1. R" MUST BE 1000 OHMS.
2. OUTPUT FREQUENCY = $\frac{R'}{1000} \times$ FREQUENCY RANGE + FREQUENCY SET WITH PANEL F_0 CONTROL

A. Continuous Range Programming Using External Potentiometer.

B. Stepped Programming Using Switched Resistive Network.

FIGURE 3-7. REAR PANEL CONNECTIONS FOR REMOTE FREQUENCY PROGRAMMING

Calculations:

1) Rf output frequency shift, Δf:

$$\Delta f = \frac{427}{1000} \times 4 \text{ Gc} - 1.708 \text{ Gc}$$

2) Actual rf output frequency = 1.708 Gc + 4.00 Gc = 5.708 Gc

Example B

Conditions:

- Same as Example A, except frequency setting 7.00 Gc (F_0 set to 7.00 Gc)

Calculations:

1) Rf output frequency shift, Δf, = 1.70 Gc (same as Example A).
2) Actual rf output frequency = 1.708 Gc + 7.00 Gc = 8.708 Gc

In the first example the output frequency is less than the upper frequency limit of the unit, and the resistor value is acceptable. In the second example the resistor value is not acceptable, because of the frequency setting of the panel controls since the calculated frequency is greater than the upper frequency limit of the plug-in unit. Connection of such a resistor would produce distortion and possibly damage the microwave tube.

Example C

Conditions:

- Plug-in unit range = 8 to 12.4 Gc; therefore frequency range = (12.4 - 8) Gc = 4.4 Gc
- Frequency setting = 8.5 Gc (F_0 set to 8.5 Gc)
- Desired external programming: step the output frequency to 9.6, 10.8, and 12.0 Gc.

Calculations:

1) Determine the output frequency shift, Δf, required for each step:

Δf_1 = (9.6 - 8.5) Gc = 1.1 Gc
Δf_2 = (10.8 - 8.5) Gc = 2.3 Gc
Δf_3 = (12.0 - 8.5) Gc = 3.5 Gc

2) Determine the corresponding value of R' for each step, using the Δf equation:

$$\Delta f_1 = 1.1 \text{ Gc} = \frac{R'_1}{1000} \times 4.4 \text{ Gc}$$

(simplify by multiplying both sides by 1000 and dividing both sides by 4.4 Gc)

$$R'_1 = 1000 \times \frac{1.1}{4.4} = 100 \times 1/4 = 250 \text{ ohms}$$

$$\Delta f_2 = 2.3 \text{ Gc} = \frac{R'_2}{1000} \times 4.4 \text{ Gc}$$

(simplify)

$$R'_2 = 1000 \times \frac{2.3}{4.4} = 523 \text{ ohms}$$

$$\Delta f_3 = 3.5 \text{ Gc} = \frac{R'_3}{1000} \times 4.4 \text{ Gc}$$

(simplify)

$$R'_3 = 1000 \times \frac{3.5}{4.4} \times 795 \text{ ohms}$$

3) Calculate the values of resistors R_A, R_B, R_C and R_{DEF} to use in the program circuit shown in Figure 3-7.

By reference to Figure 3-7, $R_A + R_B + R_C + R_{DEF}$ = 1000 ohms.

$R_A + R_B + R_C = R'_3$ calculated above = 795 ohms

Thus, R_{DEF} = 1000 ohms - 795 ohms = 205 ohms
$R_A = R'_1$ calculated above = 250 ohms
R_B = (R'_2 above - R_A) = 523 ohms - 250 ohms = 273 ohms
R_C = [R'_3 above - ($R_A + R_B$)] = 795 ohms - 523 ohms = 272 ohms

NOTE: The input impedance of the remote programming input is 15 K ohms. Because of this it is required that the total resistance of the external resistors (R") be 1 K ohms. This value is equal to that of the panel frequency controls. If some other value is used, the calibration based on the equations above will not be exact because of the different loading effect of the 15 K input impedance.

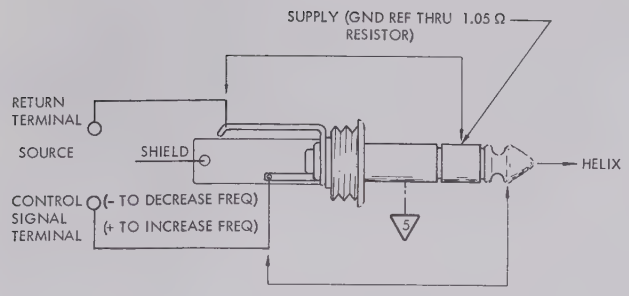
c. Connect the 1 K potentiometer or resistor circuit, set up according to the above calculations, to the REMOTE FREQ jack as shown in Figure 3-7.

3.11.3 REMOTE FREQUENCY STABILIZING AND HIGH FREQUENCY FM MODULATION (BWO PLUG-IN UNITS ONLY) (See Figure 3-8). The FREQUENCY STABILIZING input jack can be used to apply error signals from a frequency discriminator or phase discriminator for frequency - or phase-locking the Model 650 Series in any single-frequency output mode when the FREQUENCY Mode Selector switch is in the SINGLE position. It can also be used to apply high frequency fm in either swept mode, including untriggered sweep to allow fm modulation of single-frequency outputs. Modulating signal frequencies can be higher than those acceptable by the FM INPUT jack. The FREQUENCY STABILIZING input jack is a three-terminal closed-circuit phone jack located on the rear of the plug-in and accessible through a hole in the rear of the Model 650. It provides high frequency response because it applies a modulating voltage directly to the helix lead of the BWO tube. (It therefore is not available on VTM plug-in units.)

For all tubes, the voltage applied to this input should not exceed the limits of +50 volts and -50 volts. The applied signals will vary the frequency from that established by the panel controls. A positive voltage will increase the frequency, and a negative voltage will decrease the frequency. The response versus voltage is not linear, and the sensitivity and exact response characteristic depend upon the microwave tube used. These characteristics vary somewhat between individual tubes of the same model as well as between plug-in units, so that some experimentation will be required to achieve calibrated results.

The signal source required for this input must be floating and capable of supplying the required helix current to the BWO. This current requirement is given in the instruction manual for the plug-in. Since the helix is operated only a few millivolts below ground, no high voltage insulation is required.

The high frequency response of this helix modulation circuit is in the megacycle range, and is normally limited by the ability of the signal source to drive the circuit input capacitance. This capacitance, due to terminal connections and wiring, etc.,



NOTES:
1. USE SWITCHCRAFT #297 3-CIRCUIT PHONE JACK.
2. DO NOT EXCEED ± 50 V CONTROL SIGNAL.

FIGURE 3-8. REAR PANEL CONNECTIONS FOR REMOTE FREQUENCY STABILIZATION OR HIGH-FREQUENCY FM MODULATION

is about 100 pf. Frequency- and phase-lock response approaches the nanosecond range, and over-all loop stability is again usually limited by the ability of the discriminator or stabilizer used to drive the helix.

Separate procedures are given below for frequency stabilization and for high frequency fm modulation.

3.11.3.1 PROCEDURE FOR REMOTE FREQUENCY STABILIZATION. Proceed as follows:

a. Place the instrument in operation for any single-frequency mode, following the procedure of Paragraph 3-6.

b. Tap off a portion of the rf output signal through a coupler to drive the external discriminator or stabilizing device.

c. Connect the discriminator output through a shielded two-conductor cable to a three-terminal phone jack which mates with the REMOTE FREQUENCY STABILIZING jack, as shown in Figure 3-8. Be sure to observe the proper polarity sense.

d. Adjust the discriminator or stabilizer output as necessary to obtain optimum stabilization.

3.11.3.2 PROCEDURE FOR HIGH-FREQUENCY FM MODULATION. Proceed as follows:

a. For modulation in single-frequency modes, make switch settings as directed in Paragraph 3.11.1.2 a. For modulation in swept-frequency modes, make switch settings as directed in Paragraph 3.11.1.4 a.

b. Connect the modulating signal through a shielded two-conductor cable to a three-terminal phone jack which mates with the REMOTE FREQUENCY STABILIZING jack, as shown in Figure 3-8. Be sure to observe the proper polarity sense.

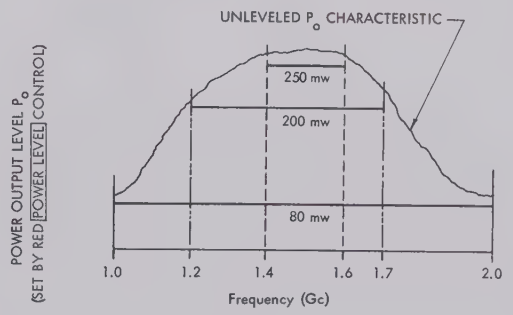
c. Note that the applied modulation must not be allowed to drive the rf output frequency outside the range of the plug-in. The instantaneous frequency output will be the indicated single-frequency dial setting plus the increment due to signal applied to the helix. Separate calculations or empirical checks must be made for each tube if a particular known deviation is required because of sensitivity variations.

3.12 RF OUTPUT LEVELING AND POWER LEVEL ADJUSTMENT.

3.12.1 GENERAL DATA (See Figures 3-9 and 3-10). All Oscillator Plug-in units include a leveler-amplifier to permit rf power output leveling and power level adjustment when used with an appropriate sampler. Plug-in units with K, AK, and CK model number suffixes have an internal rf sampler. These units can be leveled with or without an external rf sampler. Other plug-in units can provide output leveling only if an external sampler is used.

Leveling of the rf power source is useful for many applications because system output variations can then be directly attributed to the equipment under test. The power output characteristic of microwave oscillator tubes (BWO or VTM as used in the Model 650 Series) is not constant through the frequency range of each tube. A typical power output characteristic of an unleveled BWO tube is bell-shaped, with 6 to 8 db higher power at band center, and with some lesser narrow-band variations superimposed across the band. An unleveled VTM typically has a power variation of only 2 or 3 db across the band, dropping at band edges and varying randomly in between. When operating with internal leveling (K, AK, and CK plug-in units), these power variations at the RF OUTPUT connector can be held to within the limits shown in Table 1-2 for each plug-in unit (generally +0.3 db) across the full bandwidth of the plug-in unit. By using the external leveling mode (all plug-in units) with a suitable external sampler located at the load, power variations at a remote load can be kept to within the same limits.

The RF OUTPUT jack of the plug-in units with internal sampling is physically the primary ouput terminal of the internal sampling coupler. Therefore, "at-the-load" leveling performance with internal leveling can be obtained by connecting the load directly to the RF OUTPUT jack. The internal low-pass filter (BWO units) or circulator (VTM units) contained in the plug-in unit



NOTE: THE RED POWER LEVEL CONTROL ADJUSTS THE POWER LEVEL TO A POINT WHERE FULL-BAND LEVELING TAKES PLACE WHEN TURNED TO A MID-RANGE POSITION. TURNED CLOCKWISE FROM THAT POSITION, IT RAISES THE OUTPUT POWER LEVEL FOR NARROW-BAND LEVELING AS ILLUSTRATED ABOVE. TURNED COUNTERCLOCKWISE FROM THAT POSITION, IT REDUCES THE FULL-BAND LEVELED OUTPUT OVER A RANGE OF ABOUT 5 DB ON BWO UNITS, AND ON VTM UNITS WITH SOLID-STATE LEVELING (10 DB ON BWO UNITS WITH C SUFFIX).

FIGURE 3-9. TYPICAL LEVELER PERFORMANCE

provides adequate isolation with most loads. (This element is located between the microwave tube and the internal sampling coupler, and is thus within the leveled loop for either internal or external leveling.) Where the load cannot be connected directly to the RF OUTPUT jack, additional level variations will be produced in the signal supplied to the load by the unavoidable mismatch present in the connecting coaxial or waveguide line(s) and other intermediate components. In this case, improved performance can be obtained with "at-the-load" leveling using an external sampler located at the input terminal to the load.

In all units, whenever external sampling is used, the sampler should be located at the load if possible, and otherwise as close to the load as possible, to minimize VSWR-producing components between the leveled loop and the load.

The leveler-amplifier system used in ALFRED plug-in units develops an amplitude-correcting feedback signal by comparing the signal level from the internal or external sampling detector with a reference signal set by the POWER LEVEL control. A differential amplifier automatically adjusts the power level until the two signals cancel. In leveled operation, when the POWER LEVEL control setting corresponds to a level higher than the unleveled power output over part of the band, the leveler is operative over only that portion of the band that can be leveled to the selected value. On units with internal sampling, the sensitivity of the internal detector circuit is set to provide full-bandwidth leveling at a mid-range position of the POWER LEVEL control. This allows the power level to be adjusted to a higher value for narrow-band leveling. It also allows at least a 5 db adjustment of output power level with full-band leveling on BWO units, and an adjustment of up to 1 db with full-band leveling on VTM units. For external leveling, the detector used must be able to develop about -100 mv (-60 mv minimum) at the RF SAMPLER INPUT jack with the maximum output power available under full-band-leveled conditions. Input impedance of this jack is about 3 K. The RF SAMPLER SENS screwdriver control adjusts the sensitivity of the leveler-amplifier to the external sampler, to allow the detector signal to be balanced against the internal reference at the desired setting of the red POWER LEVEL control.

Full-band leveling can be provided at a level that is within 1 db of the minimum-power point of the unleveled output characteristic. Similarly, leveling over any portion of the band can be obtained at a level that is within .5 db of the minimum-power point of the unleveled output characteristic within that portion of the band. Thus, over narrow mid-band ranges where the available power is higher than at band edges, higher than rated full-band leveled power may be obtained, as shown in Figure 3-9. The UNLEVELED light goes out only when the output power is leveled over the frequency range being swept.

The basic external leveling loop for obtaining optimum power leveling at the load is shown in Figure 3-10A. It consists of a directional coupler to sample a portion of the rf output, and a detector to convert the sampled rf into a dc signal for the leveler-amplifier. An external 3 db pad or low-pass filter to isolate load mismatch from the oscillator tube is not normally required because of the internal isolation provided within the plug-in unit. The ALFRED Model 1001 Crystal Detector can be used with power levels up to 100 mw. It requires no more than 1 mw input power to develop -60 mv when driving the 3000-ohm input impedance of the RF SAMPLER INPUT jack. The Model 1001 Detectors have exceptionally uniform, matched characteristics. They provide square-law performance within 0.5 db from low level up to 1 mw, and have a sensitivity of greater than 0.5 mv/μw at low levels. These features are advantageous where the leveler sampler circuit is to be matched with the reflected power sampler circuit in reflectometer measurements, as discussed in Paragraph 3.17.3.

An improved external leveling loop using an ALFRED RF Sampler for leveling at the load is shown in Figure 3-10B. These sampler units contain crystal detectors installed directly on the secondary arm of a high-directivity coupler, providing an integrated rf-to-dc transducer with excellent matched wideband response characteristics. Performance details of each unit of the ALFRED Series of RF Sampler Series are given in Table 3-4. Output is at least -60 mv with 1 mw coupled into the detector arm. A sampler should be chosen which provides at least 1 mw into the detector arm at the output level to be used.

An alternate method of external leveling which provides an additional power level adjustment range up to 50 db is shown in Figure 3-10C. This method uses the ALFRED Models 1151-1153 Sampler Attenuators which consist of an ALFRED RF Sampler followed by a precision variable attenuator. The variable attenuator is actually a variable directional coupler and its frequency response is very carefully matched with that of the sampler, so that exceptionally flat output over a wide frequency and attenuation range is obtained. Power variation across the band at any level with a 20-db range can be held to within ± 0.5 db with this arrangement.

In units with PIN diode leveling (650A, AK, C, and CK Series Plug-in units), the output leveling is provided by solid-state attenuation in the output circuit while the oscillator tube continues to operate at full power. Thus, level correction is made independently of the tube and excellent frequency stability is maintained. In other units which have grid-leveled BWOs, some frequency pulling will take place during leveling. This is an inherent characteristic of BWO tubes. Injector-leveled VTMs exhibit a similar characteristic.

The rf output level can be adjusted in all units when operating in the leveled mode, and in all units with waveguide output and/or with A, AK, C, and CK model number suffixes when operating in the unleveled mode.

The procedures for each type of leveling and power level adjustment are given separately below.

3.12.2 LEVELING WITH INTERNAL SAMPLING (650K, AK AND CK SERIES PLUG-IN UNITS ONLY). Proceed as follows:

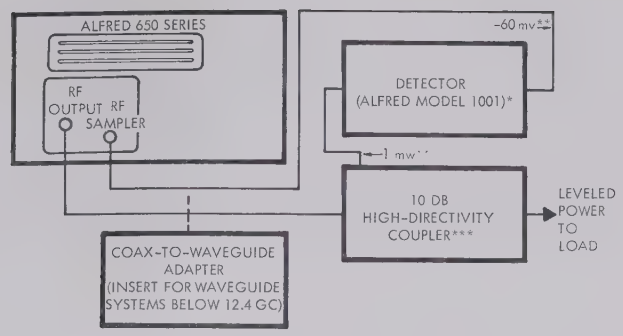
a. Set all controls (except those on the plug-in panel) as directed in the preceeding paragraphs, to obtain the desired operating conditions.

b. Make the following control settings on the plug-in panel:

RF OUTPUT Selector switch to LEVELED.
RF SAMPLER Snap switch to INT.

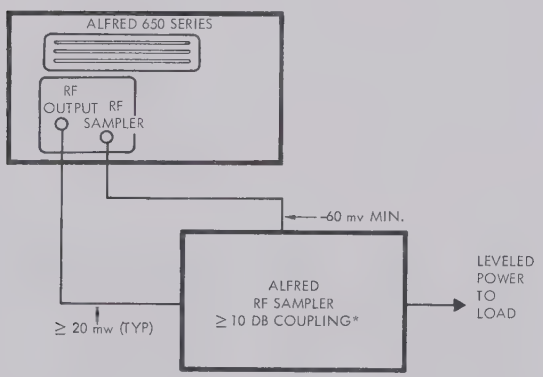
c. The red POWER LEVEL Control will reduce the leveled output power to the value required for full-band leveling on all units, and then an additional 5 db on most units* when turned from its fully clockwise position to its fully counterclockwise position (see Figure 3-9). Set this control to the desired level. The UNLEVELED light will go off when the output is leveled over the frequency band being swept. On grid-leveled VTM units, distortion may occur with reduction below the full-band leveling point. On grid-leveled BWO units, do not attempt to reduce leveled power more than 5 db below the minimum unleveled output power. On solid-state leveled units, the full

*10 db on units having C suffix.



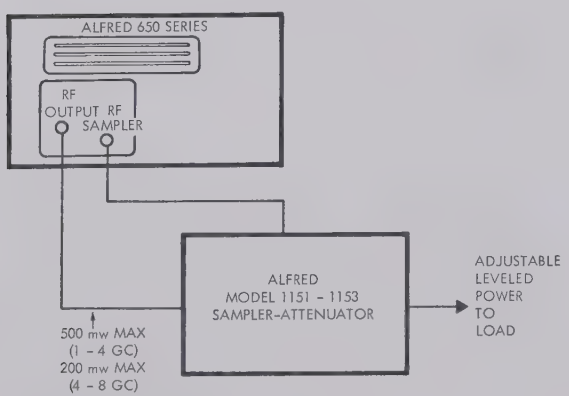
*ABOVE 12.4 GC, USE A SUITABLE ALTERNATE DETECTOR.
**MINIMUM REQUIRED FOR LEVELING AT MAXIMUM FULL-BAND LEVELED POWER.
***10-DB COUPLER SHOWN APPLIES TO PLUG-IN UNITS WITH MAXIMUM FULL-BAND LEVELED POWER OF 20 mw. USE LOWER COUPLING VALUE AND/OR INSERT A FLAT PAD BETWEEN THE COUPLER AND DETECTOR FOR PLUG-IN UNITS WITH HIGHER LEVELED OUTPUT POWER. LOCATE THIS COUPLER AS CLOSE AS POSSIBLE TO THE LOAD FOR BEST LEVELING PERFORMANCE.

A. External Leveling with Individual Components



*THE COUPLING VALUE USED MUST SUPPLY AT LEAST 1 mw TO THE INTERNAL DETECTOR WITH THE LEVEL OF OUTPUT POWER TO BE USED (SEE TABULATION IN TABLE 3-4). ABOVE 12.4 GC, USE AN EQUIVALENT WAVEGUIDE COUPLER AND CRYSTAL DETECTOR.

B. Leveling with ALFRED Sampler Located at the Load (1 - 12 Gc Coverage)


ALFRED 650 SERIES
RF OUTPUT
RF SAMPLER
ALFRED MODEL 1151 - 1153 SAMPLER-ATTENUATOR
ADJUSTABLE LEVELED POWER TO LOAD
500 mw MAX (1 - 4 GC)
200 mw MAX (4 - 8 GC)

C. Leveling with ALFRED Model 1151 - 1153 Sampler-Attenuator Located at the Load (1 - 8 Gc Coverage)

FIGURE 3-10. TYPICAL CONNECTIONS FOR EXTERNAL LEVELING

available control range may be safely used.

d. For remote control of output level, turn the red POWER LEVEL control fully clockwise and connect a level-programming network to the REMOTE POWER LEVEL banana jacks on the rear panel as shown in Figure 3-3.

3.12.3 LEVELING WITH EXTERNAL SAMPLING (ALL PLUG-IN UNITS). Proceed as follows (See Figure 3-10):

a. Connect to the RF OUTPUT line a suitable sampling coupler and detector to develop an output of -100 mv (-60 mv, minimum) corresponding to the minimum -output point in the spectrum. Connect the output of the sampler detector to the RF SAMPLER INPUT jack, which has an input impedance of approximately 3 K ohms. The ALFRED Models 1151 to 1153 Sampler-Attenuators combine a sampling coupler, detector, and attenuator in one convenient package. The ALFRED Model 1001 Crystal Detector is also available for use with standard couplers. Use high-directivity couplers to minimize leveling error due to reflected power from high-VSWR loads.

b. Set all controls (except those on the plug-in panel) as directed in the preceeding paragraphs, to obtain the desired operating conditions.

c. Make the following control settings on the plug-in panel:

RF OUTPUT Selector switch to LEVELED.
RF SAMPLER Snap switch (if present) to EXT.

d. Observe the output leveling performance across the band, by temporarily connecting the termination (or a second coupler) on the RF OUTPUT line to a power meter or oscilloscope, through a suitable detector such as the ALFRED Model 1001. Sweep across the frequency range of interest and check whether the output is leveled. Full-band leveled performance should be obtained with the red POWER LEVEL control turned to a mid-range position. This will allow higher narrow-band leveling and also provide an additional 5 db* reduction range when the control is turned fully counter-clockwise, as shown in Figure 3-9. If necessary, adjust the RF SAMPLER SENS. panel screwdriver control to provide the proper response for the detector used, to permit full-band leveling at an appropriate position of the POWER LEVEL control. The UNLEVELED light will go off only when power is leveled over the band being swept. Turning the RF SAMPLER SENS control clockwise reduces the sensitivity of the leveler amplifier to the external sampler signal and thereby raises the power level obtained for any setting of the POWER LEVEL control. This has the effect of moving the full-band leveling position of the POWER LEVEL control toward its counterclockwise limit. Turning the RF SAMPLER SENS. control counter-clockwise increases the sensitivity of the leveler-amplifier to the external sampler signal, and thereby reduces the power level obtained for any setting of the POWER LEVEL control. This has the effect of moving the full-band leveling position of the POWER LEVEL control toward its clockwise limit. If the desired leveling response cannot be obtained with any setting of the RF SAMPLER SENS. control, check whether

Table 3-4. Specifications of ALFRED Samplers[1]

Model No.	Frequency Range Gc	Mean Coupling (db) [At Center of Range]	Equivalent Source Match (Max SWR)[2]	Frequency Response (Max db)[3]	Rated Input (dbm)	Crystal Output Rated Input (Min mv)[4]	Insertion Loss (Max db) [Swept Over Range]	Maximum Input (dbm)
S150	1.0 - 2.0	17	< 1.5	± 0.3	+17	60	< 1.0	+ 37
S155	1.4 - 2.5	17	< 1.5	± 0.3	+17	60	< 1.0	+ 37
S151	2.0 - 4.0	17	< 1.5	± 0.3	+17	60	< 1.0	+ 37
S112Z	4.0 - 8.0	10	< 1.5	± 0.4	+10	60	0.7	+ 30
1161	7.0 - 12.4	13.5	1.3	± 0.4	+13	60	1.2	+ 33
1168	8.2 - 12.4	17	< 1.5	± 0.4	+17	60	0.5	+ 37

NOTES:

1. Specifications subject to change without notice. Other models are available on special order.
2. Output SWR at 6 single frequencies in range, when used in a closed loop leveling system.
3. When used in a closed loop leveling system swept over the full range, where system amplifier contributes less than 2% error.
4. Limiting value at high end of range, when crystal detector is terminated with 2.8 K (Model 650 RF SAMPLER INPUT jack).

insufficient power is reaching the external sampler detector through the sampling coupler used.

CAUTION

Adjust the RF SAMPLER SENS control with a screwdriver made of plastic or other non-ferrous material, to avoid damage to the microwave tube.

e. Follow Steps c., d., and e. of Paragraph 3.12.2 above. On waveguide output units, to obtain optimum leveled performance, the black POWER LEVEL control should initially be turned fully clockwise for maximum power output. Set the desired power level using the red POWER LEVEL control. Then for optimum performance, turn the black POWER LEVEL control counterclockwise until the UNLEVELED light comes on, and back off clockwise until the light goes off again. This provides the desired output level while allowthe tube to operate at maximum leveled power, through use of the flap attenuator. If more power level reduction than that provided by the red POWER LEVEL control is required, the black POWER LEVEL control can be used to obtain it. Note that when the black POWER LEVEL control is used to provide reduction of output level, it will reduce the output of the external leveler sampler since it is now within the rf feedback loop. Therefore, it may be necessary to adjust the RF SAMPLER SENS control to restore the desired leveled condition if the black POWER LEVEL control is adjusted.

3.12.4 EXTERNAL POWER LEVEL CONTROL AND PROGRAMING. During leveled operation with internal or external sampling, the rf power output level can be controlled over at least a 5 db* range below the full-band leveling point on most units by use of a 1 K potentiometer or adjustable resistor network connected to the REMOTE POWER LEVEL banana jacks on the rear panel.

*10 db on units having C suffix.

The arrangement is shown in Figure 3-3. If the front panel red POWER LEVEL control is turned fully clockwise, the connection to the REMOTE POWER LEVEL jacks will provide output reduction to the full-band leveling point and then at least 5 db* additional reduction, as the wiper of a 1 K potentiometer is moved between the MAX and MIN end taps. If the front panel red POWER LEVEL control is turned away from its fully clockwise position, the total control range of the connection to the REMOTE POWER LEVEL jacks will be reduced, since the two circuits are connected in parallel to generate the internal leveling reference signal.

If desired, the output can be reduced to the level where full-band leveling occurs by means of the front panel POWER LEVEL control, and then the REMOTE POWER LEVEL jacks can be used to provide a control range of about 5 db* below the full-band leveling point. This arrangement eliminates the need for achieving full-band leveling with the remote connection.

A typical response curve for remote power level control is shown in Figure 3-3. Some units with solid-state leveling provide a control range of more than 5 db* below the full-band leveling point, as illustrated. On these units, the full available range may be safely used. On grid-leveled VTM units, distortion may occur with reduction below the full-band leveling point. On grid-leveled BWO units, do not attempt to reduce leveled power more than 5 db below the minimum unleveled output power.

To use external power level control, follow the leveling procedure given above in Paragraph 3.12.2 or 3.12.3, and adjust the power level in accordance with this Paragraph and Figure 3-3.

3.12.5 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (650A, AK, C, and CK PLUG-IN SERIES ONLY). During unleveled operation, the PIN diode leveler attenuator in the rf output circuit is still operative and may be used to adjust the output level. With the RF OUTPUT Selector switch in the UNLEVELED position, the output level may be reduced by at least 5 db* from the instantaneous unleveled value by turning the red POWER LEVEL control counterclockwise. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects. On these plug-in units, this control must be left in the fully clockwise position to obtain maximum unleveled power.

3.12.6 ADJUSTMENT OF POWER LEVEL IN UNLEVELED OPERATION (650 and 650K PLUG-IN SERIES ABOVE 12.4 GC ONLY). During unleveled operation, the flap attenuator in the rf output circuit may be used to adjust the output level. This attenuator is operated by the black POWER LEVEL control knob and will reduce the output level by at least 10 db from the instantaneous unleveled value when turned counterclockwise. Since the tube continues to operate at full power, the attenuated output level is obtained without any frequency shifting effects. On these plug-in units, this control must be left in the fully clockwise position to obtain maximum unleveled power.

3.13 USE OF MARKERS

3.13.1 INTERNAL RF MARKERS. The internal rf markers can be used only when the rf output is leveled, and appear in the output as an absorptive dip in the output level. This decrease occurs when the output frequency crosses the setting of the M_1, M_2, and F_0 dial indicators in $F_1 \rightarrow F_2$ and manual sweep modes. In $F_0 \pm \Delta F$ sweep mode, only the M_1 and M_2 markers are operative. The amplitude of the marker dip is variable by the MARKER AMPLITUDE control, increasing as it is turned clockwise out of the OFF position. At the maximum setting, just before the switched EXT position, the amplitude is at least 2 db at the three slower sweep speed ranges, and at least 0.2 db in the fastest sweep speed range. The base width of the markers at maximum amplitude is approximately 0.05% of the full frequency range at all sweep speeds. The base width decreases as the amplitude is decreased. The markers do not appear during retrace if the rf is left on. These markers pips will be found to be even sharper than those obtained with a cavity wavemeter

3.13.2 EXTERNAL VIDEO MARKERS. The external rf markers are provided for use when the rf output is unleveled, and can be used in the leveled condition as well. These markers are provided to the MARKER OUTPUT jack only when the MARKER AMPLITUDE control is in the EXT switched position. They have an amplitude of about -1 V and a width of about 5 μs. Pulse width is independent of the sweep-time used. They can be applied to an oscilloscope display of the detected rf output by summing the signal from the MARKER OUTPUT jack with the detector output at the input to the oscilloscope vertical amplifier, using a BNC tee. It may be necessary to add impedance to either the detector output or video marker lines to match signal levels to obtain the desired presentation. These video markers are not provided during retrace.

The external video markers will be found useful for the following situations:

a. When output is unleveled and rf markers are not available.

b. In reflectometer applications where it is necessary to have a constant drive level to avoid spurious reflections.

c. In measurement applications where level variations in the response swamp out the low-amplitude rf markers.

d. In loss measurements of filters and attenuators where the rf markers are attenuated.

e. In test system applications where it is convenient to have a trigger pulse available when a certain frequency or frequencies are crossed to actuate programmed readout measurements, level changes, etc.

*10 db on units having C suffix.

3.14 RF OUTPUT BLANKING DURING SWEEP RETRACE.

During the sweep modes of operation, the rf power can either be on or off during sweep retrace and until the next sweep is triggered. Selection of either of these conditions is provided by the RETRACE switch. In the OFF position, the rf power is turned off during retrace by biasing the microwave tube beyond beam cut-off. Thus, no rf power appears at the RF OUTPUT connector during retrace. This permits zero reference points to be established.

3.15 AUXILIARY OUTPUT SIGNALS.

For convenience in operating the Model 650 Series with oscilloscope and recorder displays, several auxiliary output signals are supplied. These are discussed individually in the paragraphs below.

3.15.1 OUTPUT SWEEP SIGNAL. This signal is convenient for driving the oscilloscope horizontal channel or the recorder X-axis for display of swept presentations. This signal is available at the front panel OUTPUT SWEEP jack. A fixed +15 V is available from the jack for calibrating the display when the adjacent CALIB button is pressed. The OUTPUT SWEEP signal provided in each mode of operation is tabulated below. The output impedance is 10 K.

Mode:	OUTPUT SWEEP Signal:
Swept, $F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$	0 to +15 V linear sawtooth regardless of swept frequency band; 0 V at sweep start and +15 V at sweep stop.
Manual Sweep	0 to +15 V level, proportional to output frequency between F_1 and F_2; 0 V at F_1 and +15 V at F_2.
Single-Frequency, M_0, F_0, M_2	Dc level between 0 and +15 V, proportional to the position of the output frequency within the linear dial range.
Single-Frequency, F_2	Same as manual sweep; +15V when MANUAL SWEEP control is switched to F_2.
Single-Frequency, F_1	Grounded (can be used as zero-set reference).
FREQUENCY Mode Selector OFF	Dc level between 0 and +15 V, proportional to the setting of the F_0 indicator within the linear dial range.

3.15.2 OUTPUT BLANKING SIGNAL. This signal is convenient for driving the oscilloscope Z-axis to blank the presentation trace during sweep retrace. This signal is provided at the front panel OUTPUT BLANKING jack. It has a level of +50 V during retrace and until the next sweep is triggered, and is at 0 V during the sweep. The +50 V output is also supplied continuously during manual sweep, in all single-frequency modes, and when the rf output is turned OFF with the FREQUENCY Mode Selector switch. Output impedance is approximately 10 K ohms.

3.15.3 BLANKING (PEN LIFT) RELAY CONTACTS. A set of form C relay contacts is brought out to the red BLANKING

RELAY CONTACT OUTPUT banana jacks on the rear panel. The center jack is common, and the normally-open (N. O.) and normally-closed (N. C.) contact jacks are labeled. This relay is energized whenever the +50 V OUTPUT BLANKING SIGNAL is supplied (see above) if the switch above the BLANKING RELAY CONTACT OUTPUT jacks is in the ON position. When this switch is in the OFF position, the relay can never be energized. Thus, if the jacks are connected to lift a recorder pen or blank a scope trace during retrace, the adjacent switch can be turned OFF to disable the blanking or pen lift when switching temporarily to single-frequency or manual sweep operation. Because of physical response limitations of the relay, it does not operate on the two fastest sweep ranges.

3.16 REMOTE CONTROL AND PROGRAMMING.

To permit incorporation of the Model 650 Series into automated, programmed test systems, all major functions that cannot be conveniently preset with the panel controls are remotely programmable. These functions are tabulated below, with reference to a previous paragraph for details.

a. Frequency Programming: Any desired sweep start frequency and sweep bandwidth can be programmed and controlled externally. For control with voltages in the 0 to +15 V range, see Paragraph 3.11.1. For control with passive resistance networks, see Paragraph 3.11.2.

b. Amplitude Programming: Any desired amplitude level from full-on to full-off can be programmed and controlled externally. For full-range control with voltages in the 0 to +10 V range, see Paragraph 3.10.2. For control within a 5 db range using passive resistance networks in leveled operation, see Paragraph 3.10.3.

c. Power Level Programming: With internal leveling or external leveling, with a fixed-response sampler, the power level can be remotely programmed and controlled within a 5 db range using passive resistance networks. With an external sampler-attenuator, the control range can be increased. See Paragraph 3.12.

d. Sweep Recurrence Programming: Sweeps can be externally triggered at any desired recurrence rate, with a 2 V signal. See Paragraph 3.8.

3.17 APPLICATIONS INFORMATION.

3.17.1 GENERAL. The following paragraphs indicate typical test set-ups which are useful for basic swept-frequency test applications of the Model 650 Series. Included are procedures for measurement of the most commonly tested microwave parameters, including reflection coefficient, VSWR, and transmission gain or loss. Most of these set-ups can be used for single-frequency testing as well.

3.17.2 READOUT DISPLAY TECHNIQUES.

3.17.2.1 OSCILLOSCOPE READOUT DISPLAY. The fastest sweep speeds provided by the Model 650 are ideal for flicker-free oscillographic display for visual inspection and for making permanent records with an oscilloscope camera. A suitable fast-responding detector, such as the ALFRED Model 1001, must be used to properly drive the oscilloscope. The continuous, real time display of a broad swept-frequency range on the oscilloscope CRT permits instantaneous "quick-look" evaluation of performance throughout the band of interest. It also allows real-time monitoring of the effects of adjustments on the device under test.

A wide variety of oscilloscopes can be used for swept-frequency performance measurements. A low-frequency oscilloscope having a vertical bandwidth of 300 Kc or more and dc-coupled vertical and horizontal input channels is adequate. Depending on test power levels and detector characteristics, it may be necessary to use an oscilloscope with high-gain vertical sensitivity. The ALFRED Model 1001 Crystal Detector provides more than 0.5 millivolts per microwatt at low levels, with square-law performance accurate to ± 0.5 db, thus providing an output of 5 millivolts at -20 dbm. The ALFRED RF Samplers (see Table 3-4) offer similar response over their individual frequency ranges. An oscilloscope vertical sensitivity of 1 mv/cm will thus be satisfactory for many applications, but for low-VSWR reflection coefficient measurements and operation with less sensitive detectors, it will be useful to have an oscilloscope with vertical sensitivity of 100 μv/cm.

While the horizontal sweep of the oscilloscope and the frequency sweep of the Model 650 can be individually synchronized to the line or to some external timing signal, it will usually be preferable to use the Model 650 OUTPUT SWEEP signal to drive the horizontal deflection channel of the oscilloscope. This 0 to +15 V sweep signal provides an accurate frequency axis for the swept display. If the Model 650 RETRACE switch is placed in the OFF position, the oscilloscope display will automatically retrace on the zero reference line,providing a continuous zero-power reference trace in recurrent-sweep modes. When the rf is left on during retrace, or when the +50 V BLANKING OUTPUT signal is used to blank the CRT during retrace, it will be convenient to set the zero-power position of the trace to coincide with a graticule line for reference.

For certain applications, it is possible to pre-calibrate the oscilloscope CRT face with a transparent overlay or tick markings so that the familiar "grease pencil" reference calibration traces need not be made. This technique is covered in detail below. It takes advantage of the fact that if the "full power" and "no power" traces are adjusted to a pre-selected deflection, intermediate response in a flat system will appear at vertical intercepts which can be calculated and labeled in advance. This provides pre-calibration for loss and reflection coefficient measurements. It can be extended to gain measurements by coordinating the calibration markings with vertical amplifier attenuator settings. For accuracy, this technique requires use of external leveling with the sampling coupler located at the load; test power levels that allow the output response crystal detector to operate in its square law range; and maximally flat couplers and attenuators outside the leveled loop.

In other applications, where power is unleveled or where components are not flat, the test system can be calibrated in the conventional way, by using an accurate variable attenuator to duplicate the loss or offset the gain of the device under test.

3.17.2.2 RECORDER READOUT DISPLAY. The slower sweep speeds provided by the Model 650 are ideal for driving X-Y recorders to make a permanent graphic record of swept-frequency test performance. Virtually any recorder with sensitivity of 0.5 mv/in. will be satisfactory for most applications, when the ALFRED Model 1001 Crystal Detector is used. For low-VSWR reflection coefficient measurements and operation with less sensitive detectors, it will be useful to have a recorder with 0.1 mv/in. sensitivity. The graph limits should be set up by adjusting the recorder controls with the pen lifted. Then a single, manually triggered sweep can be used to obtain the test record.

The Model 650 OUTPUT SWEEP signal is ideal for driving the X-axis of the recorder. This 0 to +15 V sweep signal provides an accurate frequency axis for the swept display. If the Model 650 RETRACE switch is placed in the OFF position, the graph will automatically retrace on the zero reference line. If the rf is left on during retrace, the BLANKING RELAY CONTACT output terminals on the rear of the Model 650 can be used to lift the recorder pen automatically during retrace on either of the two slowest sweep ranges. For faithful reproduction of discontinuities in the test response, one of the manual sweep modes may be used to drive the recorder slowly through the point of interest. Manual sweep is also useful for operating recorders without automatic pen controls.

3.17.2.3 METER READOUT DISPLAY. The 100-second sweep speed, selected by turning the SWEEP TIME VERNIER control fully counterclockwise in the 10-second SWEEP TIME Selector switch position, can be used for driving displays in which the readout device is a meter. This sweep speed provides responses within the response capabilities of most meters. Swept-frequency measurements of reflection coefficient, VSWR, noise figure, and power levels can thus be made with direct-reading meters. The internal 1000-cps square-wave modulation can be used with meters which require audio modulation of the rf signal, including most VSWR and ratio meters. Manual sweep can be used to investigate points of rapid variation.

3.17.3 REFLECTOMETER TECHNIQUES FOR VSWR MEASUREMENT WITH FLAT, PRE-CALIBRATED DISPLAY. (See Figure 3-11.)

3.17.3.1 GENERAL DATA. Reflectometer test systems measure the reflection coefficient of a load by separating the reflected wave propagated in the source-to-load line from the incident power. If the incident power is leveled at the load by use of an external sampling coupler located at the load, the incident power will remain constant over the test band. A single directional coupler can then be used to measure the reflected power variations due to load mismatch.

A typical set-up is shown in Figure 3-11. An attenuator pad can be used at the output of the Model 650, if necessary to reduce the level to the values shown. The 10-db couplers or samplers used for sampling incident power for the leveler and for sampling reflected power for readout should be matched as closely as possible (and preferably should be maximally flat). The test arrangement shown in Figure 3-11 will compensate for non-flat performance of the couplers if they are matched. This is because the leveling in accordance with the curve of the first coupler will then produce a power level across the band that provides constant output from the second coupler.

To test waveguide systems below 12.4 Gc, place a coax-to-waveguide adapter at the output of the Model 650 and at the input to the detectors, unless waveguide crystal detector mounts are used. This permits use of more accurate high-directivity waveguide directional couplers. Attenuator pads, filters, and adapters placed between the Model 650 RF OUTPUT connector and the external leveling sampler will not degrade the leveling performance, provided sufficient power is supplied to the leveler detector to generate a drive of -100 mv at the point of minimum unleveled output. The level must be kept within the square-law range of the reflected power detector, if a pre-calibrated display is to be used without individual calibration using a variable attenuator. The level must be kept within the square-law range of both detectors if automatic compensation for non-flat couplers is to be obtained. Otherwise, i. e. with flat couplers, the power level applied to the leveler sampler detector can exceed the square-law range.

The reflectometer technique theoretically has excellent accuracy over a wide VSWR range. The accuracy of a VSWR measurement of 1.22 is typically ± 0.05. The lowest VSWR that can be accurately measured is limited by the directivity of the reflected power readout coupler. Low-directivity couplers permit combination of a small amount of incident power with the reflection readout line. This can be enough to produce inaccuracy when the reflection level is low. Thus, measurement of low VSWR ratios requires high-directivity couplers. For reflectometer measurements of a VSWR as low as 1.10, coupler directivity should be 30 db or greater; for a VSWR of 1.05, coupler directivity should be 35 db; for a VSWR of 1.03, coupler directivity should be 40 db. The measurement of large VSWR ratios is limited by the directivity of the incident power sampling coupler.

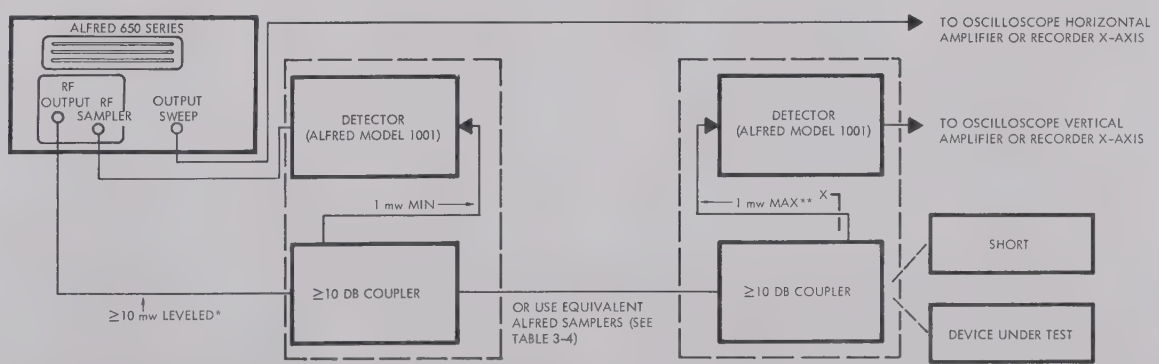
The procedure given below provides for measurements which are calibrated to a direct-reading tick-mark scale located at any convenient point on the CRT graticule or recorder graph paper. Flat, leveled performance across the band eliminates the need for recording full-width calibration traces.

3.17.3.2 DETAILED PROCEDURE. To calibrate the oscilloscope or recorder and carry out VSWR measurements, set up equipment as shown in Figure 3-11 and proceed as follows:

a. Adjust the Model 650 controls to establish the desired sweep mode and external leveling.

b. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

c. Adjust the oscilloscope or recorder horizontal gain control



*FOR DEVICES REQUIRING LOWER LEVEL, REDUCE OUTPUT BY MEANS OF POWER LEVEL CONTROL OR ADD A FLAT PAD BETWEEN THE TWO COUPLERS.
**DO NOT EXCEED THE SQUARE-LAW RANGE OF THE DETECTOR CRYSTAL WHICH DRIVES THE OSCILLOSCOPE. (ALFRED DETECTORS GIVE SQUARE-LAW PERFORMANCE WITHIN ± 0.5 DB UP TO ABOUT 1 mw.) ABOVE 12.4 GC USE A SUITABLE ALTERNATE DETECTOR OR SAMPLER.
X - FOR CALIBRATION OF INDIVIDUAL TEST SET-UPS, INSERT A PRECISION VARIABLE ATTENUATOR AT POINT X.

FIGURE 3-11. REFLECTION COEFFICIENT (VSWR) MEASUREMENTS USING CALIBRATED OSCILLOSCOPE OR RECORDER

to obtain the desired calibration in Gc per cm or Gc per inch from the Model 650 OUTPUT SWEEP drive signal.

d. Adjust the oscilloscope vertical offset controls to place the trace on the lowest horizontal line of the graticule (3 cm from center on a standard 6-cm scope). Adjust the recorder zero position as necessary to place the pen over the bottom line on the graph. This line corresponds to zero reflection (infinite return loss), which can be calibrated as 1.00 on a direct-reading VSWR scale on the CRT face or recorder chart paper.

NOTE: Detector output connections should be made with proper polarity to provide up-scale deflection on the oscilloscope or recorder.

e. Place a 100% short on the output end of the readout coupler.

f. Turn the MODULATION Selector switch to AM OFF and check for leveled output by observing that the UNLEVELED light is not lit. Adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the top line of the graticule or graph paper. Do not readjust the zero position controls. If the detected output level is above the square-law range of the detector used, reduce the Model 650 output power with the POWER LEVEL control. The line now being traced represents 100% reflection or 0 db return loss, which can be calibrated as ∞ on a direct-reading VSWR scale on the CRT face or recorder chart paper.

g. Remove the reflectometer short installed in Step e. above and observe the display with the output open-circuited. Approximately the same deflection should be obtained, since the open circuit discontinuity reflects most of the power with a minimum of transmission. If the deviation from full-scale deflection is within ± 10%, adjust the vertical amplifier vernier control halfway between the settings that place the "short" and "open" ∞ VSWR reference line on the desired scale division. If substantial difference exists between these two calibration lines, investigate the source of error in the measurement system, which may be a low-directivity coupler.

h. The direct-reading VSWR scale may now be calibrated for the full range of VSWR from 1 to ∞ by using a slide rule, a ruler or scale calibrated in divisions of the unit spacing on the CRT graticule or recorder graph paper, and the following equations:

(1) Reflection coefficient equation:

$$\rho = \frac{E \text{ reflected}}{E \text{ incident}} = \frac{VSWR - 1}{VSWR + 1}$$

$$= \sqrt{\frac{P \text{ reflected}}{P \text{ incident}}} \quad \begin{array}{l}\text{as measured with voltage signals} \\ \text{from a square-law detector.}\end{array}$$

(2) VSWR equation:

$$VSWR = \frac{1 + \rho}{1 - \rho}$$

where VSWR = ratio of the maximum to minimum voltage in the standing wave along the transmission line;
ρ = magnitude of the reflection coefficient;
$-20 \log \rho$ = definition of return loss.

Example A

Calibrate the vertical center point of the 1.00-to-∞ VSWR display:

At the center point, the detector output signal is 1/2 that at full reflection. Since the trace made with full reflection corresponds to the incident power level, the reflected signal which gives a center-scale deflection has 1/2 the power of the incident wave because square-law detector readings are directly proportional to power. From equation (1) above,

$$\sqrt{.5} = \rho = 0.707$$

from equation (2),

$$VSWR = \frac{1.707}{.293} = 5.83$$

Example B

Similarly, for a 6-unit scale such as a standard 6-cm CRT graticule, the divisional calibration points between 1.00 and ∞ can be calculated as 2.38, 3.73, 5.83, 9.9, and 22.

i. If the VSWR is below 2.0, it will be convenient to increase the vertical amplification of the oscilloscope or recorder by a factor of 10 or more, to increase the sensitivity of the direct-reading display. The scale must then be re-calibrated since the ∞ VSWR line which represents incident power is effectively moved off-scale by an amount equal to the full-scale deflection times the change in amplification. The 1.00 VSWR line remains unchanged and the display is effectively expanded.

Example A

Calculate the new VSWR values to calibrate the half-scale and full-scale VSWR lines when input amplification is increased by 10:1.

At full scale deflection, since the ∞ VSWR line (which represents incident power) has been moved a distance of 10 scale amplitudes above the scale, the reflected wave has 1/10 the power of the incident wave. From equation (1),

$$\rho = \sqrt{\frac{1}{10}} = .316$$

from equation (2)

$$VSWR = \frac{1.316}{.684} = 1.93$$

Similarly, at half scale, the reflected wave has 1/20 the power of the incident wave and

$$\rho = \sqrt{\frac{1}{20}} = .229$$

$$VSWR = 1.59$$

Example B

Similarly, for 10:1, 20:1, 50:1, and 100:1 amplification increases, the scale divisions for a 6-unit scale will be tabulated below:

Amplification	10:1	20:1	50:1	100:1
VSWR	1.00	1.00	1.00	1.00
	1.30	1.20	1.12	1.085
	1.45	1.30	1.18	1.122
	1.58	1.38	1.22	1.152
	1.70	1.45	1.26	1.18
	1.81	1.51	1.30	1.20
	1.93	1.58	1.33	1.22

j. Connect the device under test to the output end of the readout coupler. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, switch to the vertical channel amplification step that brings the trace closest to full-scale deflection. Then select the precalibrated scale corresponding to the amplification setting used and read the VSWR directly from the display.

k. Obtain recorder plots or oscilloscope photos for permanent record as desired.

l. Repeat Steps j. and k. for all devices to be tested.

3.17.4 REFLECTOMETER TECHNIQUES FOR VSWR MEASUREMENT WITHOUT FLAT DISPLAY. (See Figure 3-11.)

3.17.4.1 GENERAL DATA. In some test situations, it will not be possible to use the flat, tick-mark-calibrated readout display method outlined above. These situations include set-ups where the reflected power detector must be operated above square-law level, where a non-flat pad must be used to reduce the power level outside the leveled loop, where the leveler sampling coupler cannot be located next to the reflectometer output coupler for true incident power leveling, or where internal leveling is used.

In such cases, a variable precision attenuator can be inserted into the system between the reflectometer output coupler and the reflected power detector to calibrate the system. Usually, calibration lines the full width of the display will be required to calibrate the display because of level variations across the band. These can be traced in grease-pencil on a CRT graticule overlay, or recorded in a contrasting color on the X-Y recorder graph.

For this test method, use the test set-up shown in Figure 3-11 except that external leveling is optional, and the attenuator must be added at point X. Refer to the text discussion in Paragraph 3.17.3.1 for additional data on the reflectometer instrumentation technique. Follow the procedure given below.

3.17.4.2 DETAILED PROCEDURE. To calibrate the oscilloscope or recorder and carry out VSWR measurements, proceed as follows:

a. Follow Steps a. through e. of 3.17.3.2 with changes as required by the differences in test set-up used.

b. Turn the precision variable attenuator at point X to 0 db.

c. Turn the MODULATION Selector switch to AM OFF and check for leveled output by observing that the UNLEVELED light is not lit.

d. To make an individual measurement, connect the device under test to the output end of the readout coupler. Adjust the oscilloscope or recorder controls to obtain a performance trace at near-full-scale deflection. Note this trace on the display. Then, without adjusting the display controls, substitute the 100% short and adjust the precision variable attenuator to produce a calibration trace which intersects the performance trace. Several settings of the precision variable attenuator may be required to calibrate the performance trace at different points of intersection, depending upon the variation of VSWR over the band tested. The db readings obtained from the precision variable attenuator can be read directly as "return loss," which equals $-20 \log_{10} \rho$. These readings can thus be converted to ρ and then to VSWR.

Example A

The precision attenuator reading at one point of intersection between the performance and calibration traces is 26 db. Calculate the VSWR:

From equation (2) under Step h. of 3.17.3.2 above,

$$26 = 20 \log_{10} \rho$$

$$\log_{10} \rho = \frac{-26}{20} = -1.3$$

$$\rho = 10^{-1.3} = 0.05$$

$$VSWR = \frac{1.05}{.95} = 1.1$$

Example B

Other values can be calculated as above or found in standard microwave reference handbooks.

e. To calibrate the display for a series of measurements using the precision variable attenuator, several calibration traces as above can be made for various attenuator settings with the reflectometer output shorted. If a different setting of the recorder or oscilloscope input amplifier is required to bring the trace into position when a device is tested, the db equivalent of that amplification change must be added to the "return loss" value in computing equivalent VSWR. If the crystal is operating in its square-law range, the db equivalent of the amplification change is 10 times the $\log_{10}$ of the voltage amplification added. For optimum results, and particularly if there is any doubt as to crystal performance, run calibration traces at the same amplification setting that gives on-scale readout with the device under test.

f. Obtain recorder plots or oscilloscope photos for permanent record as desired.

g. Repeat Steps d. or e. and f. for all devices to be tested.

3.17.5 BASIC TECHNIQUE FOR MEASUREMENT OF GAIN AND LOSS. (See Figure 3-12.)

3.17.5.1 GENERAL DATA. The basic test set-up for measurement of gain and loss can be used for gain vs. frequency measurements, loss vs. frequency measurements, dynamic range measurements, stability measurements, or for measurements of a controlled gain or loss parameter vs. the control parameter. A typical set-up, which can be modified to suit an individual situation, is shown in Figure 3-12.

The precision variable attenuator permits exact calibration of the gain or loss performance in db, and allows reduction of the input level to the equipment under test, if required by its sensitivity range. The pad attenuator at the output of the equipment under test minimizes output reflections.

For loss measurements where the output level obtained from the equipment under test is much below -20 dbm, it is often advantageous to use a low-noise TWT amplifier, such as an instrument of the ALFRED 5000 Series, to raise the level to the sensitivity range of standard detectors. For gain measurements, to avoid exceeding the maximum power dissipation of the detector, the precision variable attenuator can be used to reduce the input signal level at the equipment under test, or a larger attenuator can be connected to the equipment output. Use the technique which best suits the sensitivity and performance ranges of the equipment under test. The detected output can be applied

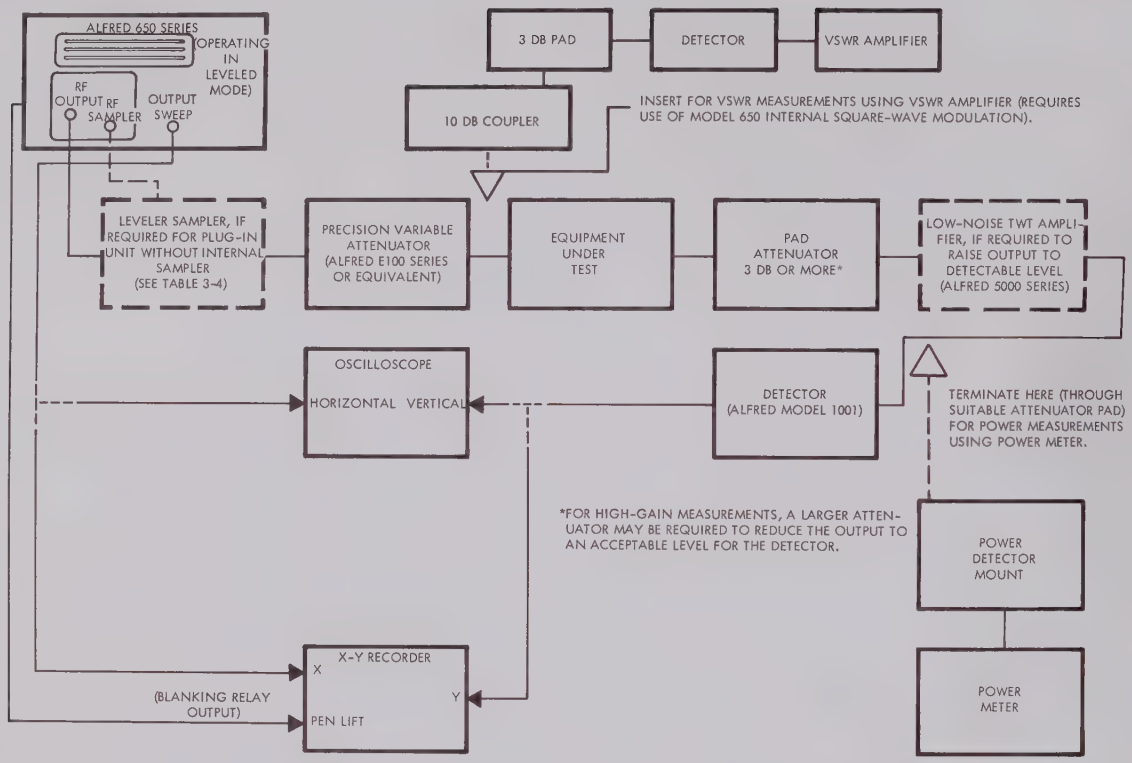

ALFRED 650 SERIES
OPERATING IN LEVELED MODE)
RF OUTPUT
RF SAMPLER
OUTPUT SWEEP
3 DB PAD
DETECTOR
VSWR AMPLIFIER
10 DB COUPLER
INSERT FOR VSWR MEASUREMENTS USING VSWR AMPLIFIER (REQUIRES USE OF MODEL 650 INTERNAL SQUARE-WAVE MODULATION).
LEVELER SAMPLER, IF REQUIRED FOR PLUG-IN UNIT WITHOUT INTERNAL SAMPLER (SEE TABLE 3-4)
PRECISION VARIABLE ATTENUATOR (ALFRED E100 SERIES OR EQUIVALENT)
EQUIPMENT UNDER TEST
PAD ATTENUATOR 3 DB OR MORE*
LOW-NOISE TWT AMPLIFIER, IF REQUIRED TO RAISE OUTPUT TO DETECTABLE LEVEL (ALFRED 5000 SERIES)
OSCILLOSCOPE
HORIZONTAL VERTICAL
DETECTOR (ALFRED MODEL 1001)
TERMINATE HERE (THROUGH SUITABLE ATTENUATOR PAD) FOR POWER MEASUREMENTS USING POWER METER.
*FOR HIGH-GAIN MEASUREMENTS, A LARGER ATTENUATOR MAY BE REQUIRED TO REDUCE THE OUTPUT TO AN ACCEPTABLE LEVEL FOR THE DETECTOR.
POWER DETECTOR MOUNT
POWER METER
X-Y RECORDER
X
Y
(BLANKING RELAY OUTPUT)
PEN LIFT

FIGURE 3-12. GENERAL-PURPOSE TEST SET-UP FOR SWEPT OR SINGLE-FREQUENCY MEASUREMENTS

either to an oscilloscope or recorder Y-axis, or to a meter.

3.17.5.2 DETAILED PROCEDURE. To make gain or loss measurements using the general set-up of Figure 3-12, a typical procedure is as follows:

a. Refer to Figure 3-12 and make rough calculations of necessary pad attenuator values and/or the minimum setting of the precision attenuator to assure that permissible power levels will not be exceeded, either at the equipment under test or at the detector. Determine whether additional pre-detection amplification will be required. Complete the test set-up, making necessary modifications from the typical arrangement shown in Figure 3-12 and setting the attenuator level(s).

b. Adjust the Model 650 controls to establish the desired sweep and leveling mode.

c. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

d. Adjust the oscilloscope or recorder horizontal gain control to obtain the desired calibration in Gc per cm or Gc per inch.

e. Turn the MODULATION Selector switch to AM OFF to supply rf output. Adjust the recorder or oscilloscope vertical controls as necessary to obtain a good presentation. Then record a single performance trace on the recorder, or preserve the oscilloscope performance trace with a grease-pencil mark. Note the precision attenuator setting at which the trace is obtained. (If measurement of dynamic range is desired, make additional trace measurements with different settings of the precision attenuator, and note both these attenuator settings and the gain settings of the recorder or oscilloscope. If the latter must be changed, make changes only in the calibrated step amplification settings, not in the vernier.)

f. Remove the equipment under test from the test circuit, connecting the precision variable attenuator directly to the equipment output pad attenuator.

g. Without adjusting the oscilloscope or recorder controls, change the setting of the precision attenuator to produce a calibration trace which intersects the previously-recorded performance trace. Record several calibration traces, with different settings of the precision attenuator, to calibrate the performance trace at various points of intersection. The points of intersection of each calibration trace with the previously-recorded performance trace will calibrate that trace in db. The difference in db between the precision attenuator setting of each calibration trace, and that used for recording the performance trace, is the absolute db value of performance for each point of intersection. Interpolation can be used between calibration traces. [If several performance traces were made using different display gain settings, obtain additional calibration traces for those gain settings, or correct the existing calibration traces for those conditions, by taking into account the db value of the amplification change: The gain increment in db = 10 $\log_{10}$ (amplification decrease) when the crystal is in its square law range.]

h. Obtain recorder plots or oscilloscope photos for permanent record as desired.

i. Repeat Steps e. through h. for all devices to be tested.

3.17.6 TECHNIQUE FOR TRANSMISSION MEASUREMENTS WITH FLAT, PRE-CALIBRATED DISPLAY (See Figures 3-13 and 3-14).

3.17.6.1 GENERAL DATA. A technique similar to that

discussed in Paragraph 3.17.3 can be used for gain or loss measurement by comparing the incident and transmitted power levels. If the incident power is leveled at the load by use of an external sampling coupler located at the load, the incident power will remain constant over the test band. A single sampler or a detector connected directly to the device output, depending upon output level, can then be used to measure the transmitted power. In some test situations, it will not be possible to use a flat, tick-mark-calibrated readout display method outlined here, and the general procedure given in Paragraph 3.17.5 must be used. These situations include cases where high VSWR exists or where significant phase shift changes take place across the band with moderate VSWR; where the transmitted power detector must be operated above square-law level; where the output power cannot be leveled at the load or where a non-flat pad must be used to reduce the power level outside the leveled loop; and where non-flat couplers are used and the leveler sampler detector must operate above square-law range, thereby preventing automatic coupler compensation.

General test set-ups for loss measurements are shown in Figure 3-13, and a general set-up for gain measurement is shown in Figure 3-14. The basic test circuit is similar to that shown in Figure 3-11 for reflectometer measurements, except that the equipment under test is placed between the two couplers. Note that in the test set-ups shown in Figures 3-13 and 3-14, the operating power levels are kept within the square-law range of ALFRED Model 1001 Detectors. A pad attenuator can be used at the output of the Model 650 as necessary to reduce the level to the values shown. It is preferable to use maximally flat samplers or couplers, but the test circuits shown in Figures 3-13A and 3-14 will compensate for variations in coupler response across the band if matched couplers are used.

In Figure 3-13A, where the incident power sampling coupler and the output power sampling coupler are of identical value, the use of matched couplers with detectors in the square-law range will allow the couplers to compensate for each other. For greatest accuracy, the couplers used should have high directivity. In testing waveguide systems below 12.4 Gc, place a coax-to-waveguide adapter at the output of the Model 650 and at the input to the detectors, unless waveguide crystal detector mounts are used. This permits use of more accurate high-directivity waveguide directional couplers.

In set-ups where the detector is connected directly to the output of the equipment under test, or where different coupling values must be used to obtain workable power levels at the input and output, maximally-flat samplers or couplers must be used. Figure 3-14 shows how a maximally-flat coupler can be simulated for the leveler sampler loop by using two identical matched 3-db couplers in tandem. The detector arm of the first coupler is connected through the primary path of an identical matched coupler whose secondary terminal is terminated in a load. This technique does not apply to couplers of other values, however, unless they are specifically designed to provide matched compensation at different power levels.

Note that if an output coupler is used for gain tests it is not usually possible to use identical matched couplers for input and output power sampling because the power supplied to the leveler detector under such conditions would not provide sufficient output for leveling. Because of phase considerations in the leveling loop, it is not possible to add dc amplification between the leveler detector output and the RF SAMPLER INPUT jack. The maximum permissible gain in the leveling loop is that obtained when the RF SAMPLER SENS control is turned fully CCW. Thus, in gain tests where flat pads or flat couplers are not available, and in other test situations where matched couplers are not available, it may be preferable to use the general procedure with a precision variable attenuator for calibration of non-flat response, as given in Paragraph 3.17.5.

The procedures given below provide for loss and gain measurements which are calibrated to a direct-reading tick-mark scale located at any convenient point on the CRT graticule or recorder graph paper. Subject to the limitations discussed above, flat, leveled performance across the band eliminates the need for recording full-width calibration traces.

3.17.6.2 LOSS MEASUREMENT PROCEDURE. To calibrate the oscilloscope or recorder and carry out loss measurements, set up equipment as shown in Figure 3-13, and proceed as follows:

a. Adjust the Model 650 controls to establish the desired sweep mode and external leveling.

b. Turn the MODULATION Selector switch to AM EXT to turn off the rf output while maintaining the OUTPUT SWEEP signal.

c. Adjust the oscilloscope or recorder horizontal gain control to obtain the desired calibration in Gc per cm or Gc per inch, from the Model 650 OUTPUT SWEEP drive signal.

d. Adjust the oscilloscope vertical offset controls to place the trace on the lowest horizontal line of the graticule (3 cm from center on a standard 6-cm scope). Adjust the recorder zero position as necessary to place the pen over the bottom line on the graph. This line corresponds to infinite attenuation (zero signal), which can be calibrated as ∞ on a direct reading scale of loss.

   NOTE: Detector output connections should be made to allow up-scale deflection on the oscilloscope or recorder.

e. In the circuit of Figure 3-13A, connect the input and output sampling couplers together at the point where the device under test would normally be inserted. In the circuit of Figure 3-13B, connect the output detector (and pad, if used) directly to the input sampling coupler, bypassing the device under test.

f. Turn the MODULATION Selector switch to AM ON and check for leveled output by observing that the UNLEVELED light is not lit. Adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the top line of the graticule or graph paper. Do not readjust the zero position controls. If the detected output level is above the square-law range of the detector used, reduce the Model 650 output power with the POWER LEVEL control.

   The line now being traced represents zero attenuation (full-strength signal). It can be calibrated as 0 db on a direct-reading attenuation scale on the CRT face or recorder chart paper.

g. The direct-reading attenuation scale may now be calibrated for the full range of attenuation from 0 db to ∞ by using a slide rule, a ruler or scale calibrated in divisions of the unit spacing on the CRT graticule or recorder graph paper, and the following equation:

   (1) Definition of db ratios:

$$\frac{E_1}{E_2}\ \text{db} = 20 \log \frac{E_1}{E_2}$$

$$= 10 \log \frac{P_1}{P_2}$$

as measured with voltage signal from a square-law detector.

Example A

Calibrate the vertical center point of the 0 db to ∞ attenuation scale:

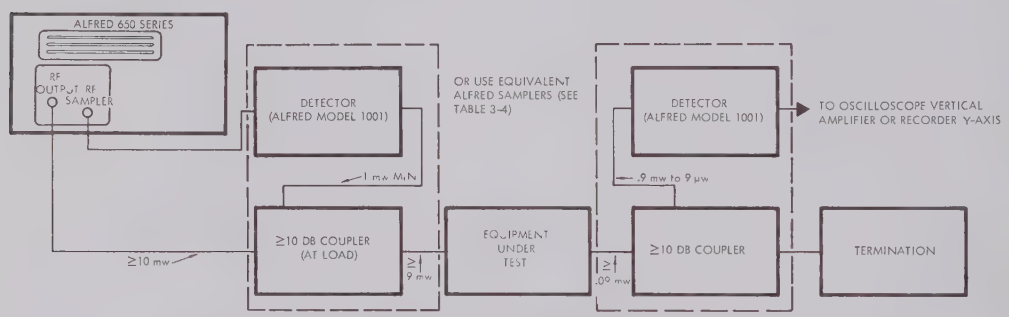
At the center point, the detector output signal is 1/2 that at the "0 db" point. Since the 0 db trace corresponds to the incident power level, the output signal which gives a center-scale deflection has 1/2 the power of the incident wave because square-law detector readings are directly proportional to power. From equation (1) above,

$$db = 10 \log \frac{2}{1} = 3 \text{ db}$$

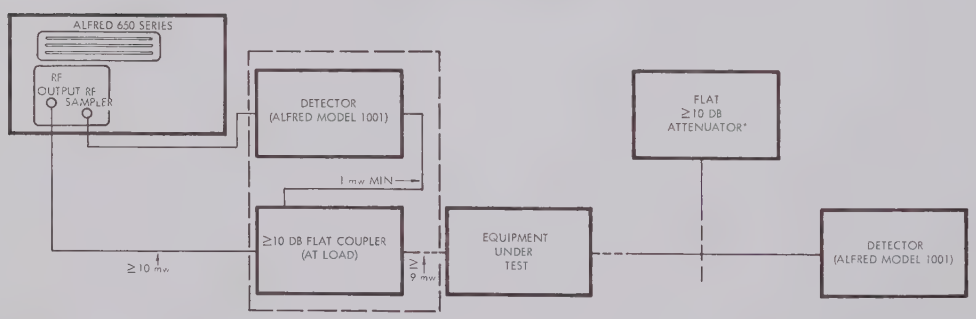
Example B

Similarly, for a 6-unit scale such as a standard 6-cm CRT graticule, the divisional calibration points between 0 and ∞ can be calculated as 0.8 db, 1.8 db, 3.0 db, 4.8 db, and 7.8 db.

h. If the loss is more than 10 db, it will be convenient to increase the vertical amplification of the oscilloscope or recorder by a factor of 10 or more to increase the sensivitity of the direct-reading display. The db value of the amplification increase must be added to the loss read directly from the calibrated scale. If the output detector crystal is operating in its square-law range, the db value is 10 times the



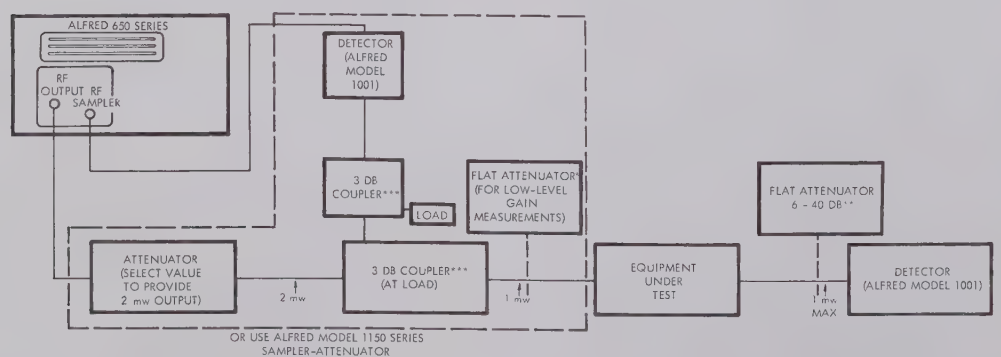
A. Measurement of 0 - 20 db Loss with Matched Couplers


ALFRED 650 SERIES
RF OUTPUT RF SAMPLER
DETECTOR (ALFRED MODEL 1001)
FLAT ≥10 DB ATTENUATOR*
1 mw MIN
≥10 DB FLAT COUPLER (AT LOAD)
EQUIPMENT UNDER TEST
DETECTOR (ALFRED MODEL 1001)
≥10 mw
≥ 9 mw
OR USE EQUIVALENT FLAT ALFRED SAMPLER (SEE TABLE 3-4)

*INSERT FOR SETTING NO-LOSS REFERENCE LINE, AND FOR MEASUREMENT OF LOSSES LESS THAN 10 DB, TO AVOID EXCEEDING SQUARE-LAW RANGE OF DETECTOR; OR USE EQUIVALENT FLAT ALFRED SAMPLER WITH TERMINATION INSTEAD OF ATTENUATOR-DETECTOR COMBINATION, AND A SEPARATE MODEL 1001 DETECTOR WHEN ATTENUATION IS NOT NEEDED. TO MEASURE LOSS >40 DB, USE HIGHER RF POWER AND CORRESPONDINGLY GREATER CALIBRATION ATTENUATION.

B. Measurement of Loss with Flat Components

FIGURE 3-13. TRANSMISSION LOSS MEASUREMENTS USING CALIBRATED OSCILLOSCOPE OR RECORDER


ALFRED 650 SERIES
RF OUTPUT RF SAMPLER
DETECTOR (ALFRED MODEL 1001)
3 DB COUPLER***
LOAD
FLAT ATTENUATOR* (FOR LOW-LEVEL GAIN MEASUREMENTS)
FLAT ATTENUATOR 6 - 40 DB**
ATTENUATOR (SELECT VALUE TO PROVIDE 2 mw OUTPUT)
3 DB COUPLER*** (AT LOAD)
EQUIPMENT UNDER TEST
DETECTOR (ALFRED MODEL 1001)
2 mw
1 mw
1 mw MAX
OR USE ALFRED MODEL 1150 SERIES SAMPLER-ATTENUATOR

*SET-UP SHOWN PROVIDES FOR 0 DBM MEASUREMENTS. FOR LOW-LEVEL GAIN MEASUREMENTS, INSERT A FLAT PAD ATTENUATOR AT THE LOAD INPUT TO REDUCE THE LEVEL TO THE DESIRED VALUE, OR USE ALFRED MODEL 1150 SERIES SAMPLER-ATTENUATOR.
**INSERT SUITABLE ATTENUATOR TO AVOID EXCEEDING SQUARE-LAW RANGE OF DETECTOR.
***TANDEM CONNECTION OF MATCHED 3 DB COUPLERS SIMULATES FLAT COUPLER.

FIGURE 3-14. TRANSMISSION GAIN MEASUREMENTS USING CALIBRATED OSCILLOSCOPE OR RECORDER

$\log_{10}$ of the voltage amplification added: 10:1 = 10 db; 20:1 = 13 db; 50:1 = 17 db; 100:1 = 20 db. With these db values added, the scale can be read directly as previously calibrated.

i. Connect the device under test between the input and output couplers as shown in Figure 3-13. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, read the attenuation from the calibrated scale. If necessary, switch to another vertical channel amplification step that brings the trace closest to full-scale deflection. Then add the db value of the added amplififcation to the scale reading as directed in Step h.

j. Obtain recorder plots or oscilloscope photos for permanent record as desired.

k. Repeat Steps i. and j. for all devices to be tested.

3.17.6.3 GAIN MEASUREMENT PROCEDURE. To calibrate the oscilloscope or recorder and carry out gain measurements, set up equipment as shown in Figure 3-14, and proceed as follows:

a. Follow Steps a. through c. under Paragraph 3.17.6.2.

b. Follow Steps d. through f. under Paragraph 3.17.6.2, except in Step f. adjust the oscilloscope or recorder vertical attenuator and calibration vernier controls as required to place the trace on the CENTER line of the graticule or graph paper, not the top line. Also, do not mark calibrations on the scale; merely obtain reference points of 0 signal (bottom line) and full-strength signal (center line).

NOTE: To calibrate the set-up used for high gain measurements, it may be necessary to remove the attenuation from the output circuit when bypassing the device under test for calibration purposes, to restore the signal to a level commensurate with that to be measured during the test. Before making test measurements, re-insert the attenuation in the output circuit.

c. Use the zero offset controls to move the "full-strength signal" trace from the center line to the bottom line of the CRT graticule or graph paper. This becomes the 0 db gain reference.

d. Calculate scale values to calibrate the graph paper or graticule, based on the relation of each scale deflection point to the known half-scale deflection offset which represents the incident signal level. Use the equation given in Step g. of 3.17.6.2 above.

Example A

Calibrate the scale division points on a 6-cm scale:

Bottom Line: 0 db gain reference.

1st division: Power Level = 1 1/3 that of incident signal, since incident signal is calibrated for half-scale deflection before offset.
10 log 1.33 = 1.24 db.

2nd division: output = 1.66 x incident power
10 log 1.66 = 2.2 db.

3rd (center) division: 10 log 2 = 3 db

4th division: 10 log 2.33 = 3.67 db

5th division: 10 log 2.66 = 4.25 db

Top Line: 10 log 3 = 4.77 db

e. If the gain is more than 4.75 db, it will be necessary to decrease the vertical amplification of the oscilloscope sufficiently to bring the trace on-scale. In order to retain the scale calibration established above, this change of sensitivity must be made with only the stepped adjustment control, without changing the zero or calibration vernier adjustments previously set to calibrate the trace. The db value of any amplification decrease must be added to the gain read directly from the calibrated scale. If the output detector crystal is operating in its square-law range, the db value is 10 times the $\log_{10}$ of the amplification change ratio: 2:1 = 3 db; 5:1 = 7 db; 10:1 = 10 db; 20:1 = 13 db; 50:1 = 17 db; 100:1 = 20 db, etc.

NOTE: If the calibration was performed with the output detector connected directly to the primary output terminal of the input coupler, the db value of the output attenuator or coupler which was bypassed for calibration must be added to the gain read directly from the calibrated scale during performance measurements. If in this case the vertical amplification must be increased to obtain an on-scale test measurement presentation, the db value of this increase must be subtracted from the gain reading. Hence, the scale in this case is augmented by an amount equal to the output attenuator loss or coupler ratio, less any increase in vertical amplification in db.

f. Connect the device under test into the test circuit as shown in Figure 3-14. Without changing the zero or calibration vernier adjustments previously set to calibrate the trace, read the attenuation from the calibrated scale. If necessary switch to another vertical channel amplification step that brings the trace closest to full-scale deflection. Then interpret the db value of the scale reading as directed in Step e.

g. Obtain recorder plots or oscilloscope photos for permanent record as desired.

h. Repeat Steps f. and g. for all devices to be tested.

3.17.7 TECHNIQUE FOR VSWR MEASUREMENTS WITH DIRECT-READING METERS. A direct-reading VSWR meter may be connected to the reflected power detector output shown in Figure 3-11, replacing an oscilloscope or recorder. The proper location for connection of a direct-reading VSWR meter is also shown in Figure 3-12. A direct-reading ratio meter may be driven by using internal leveling in the Model 650 and utilizing the incident power sampling coupler shown in Figures 3-11 and 3-12 to drive the reference channel of the ratio meter. Measurement techniques using these specialized meters are covered adequately in the instruction manuals for such meters. They may be used with either single-frequency operation or slow (100-second sweep) swept-frequency operation.

3.17.8 TECHNIQUE FOR POWER MEASUREMENT WITH DIRECT-READING METERS. A direct-reading power meter may be used by terminating the output circuit from the device under test at its power detector mount. The connection must be made through a suitable attenuator pad (or a coupler) to reduce the incident power level to that acceptable to the detector mount, which is usually 10 mw maximum. Measurement techniques are covered adequately in the instruction manuals for these meters. For greatest accuracy, single-frequency operation should be used. With some power meters, slow (100-second sweep) swept-frequency operation may be used.

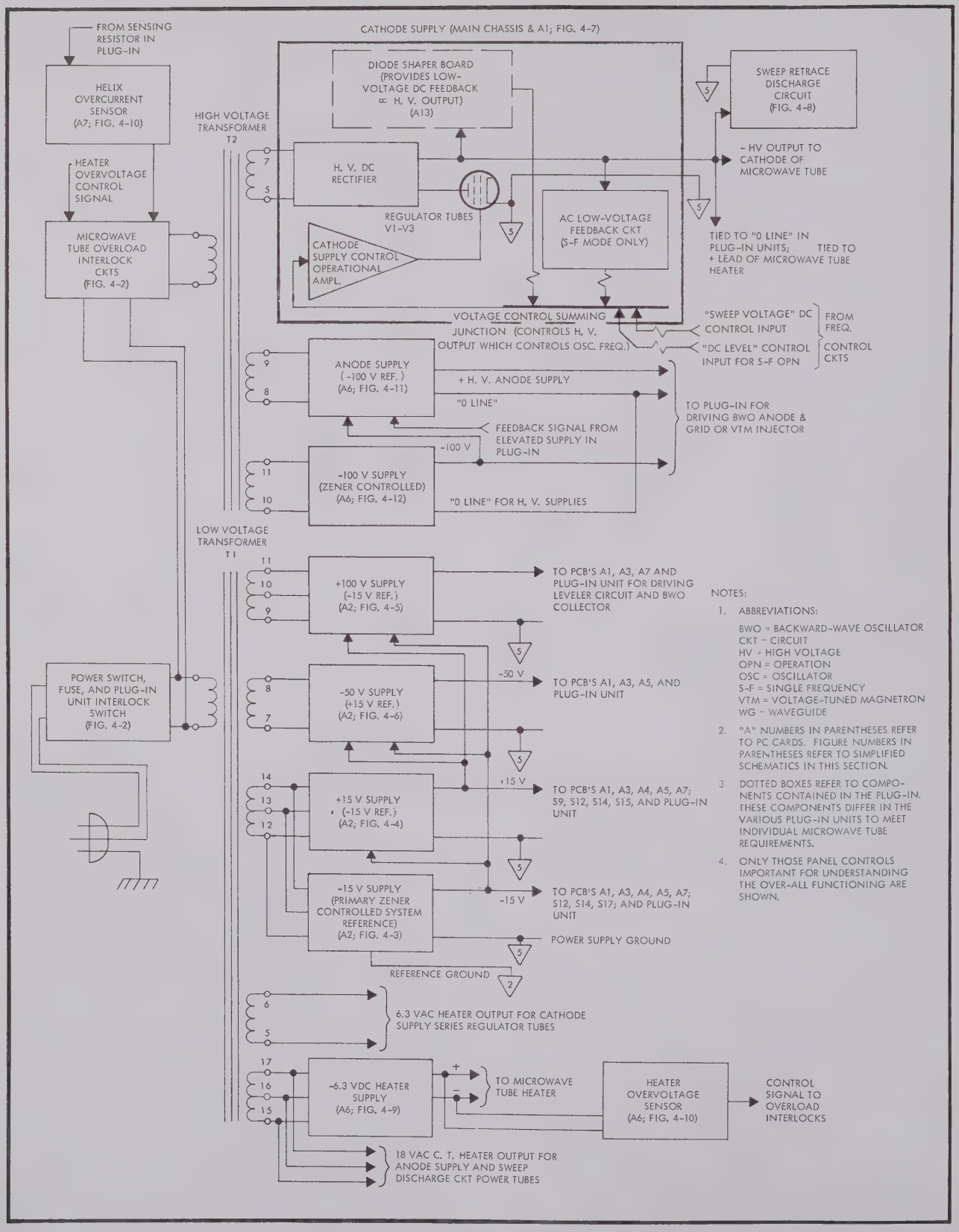

FROM SENSING RESISTOR IN PLUG-IN
HELIX OVERCURRENT SENSOR (A7; FIG. 4-10)
HEATER OVERVOLTAGE CONTROL SIGNAL
MICROWAVE TUBE OVERLOAD INTERLOCK CKTS (FIG. 4-2)
POWER SWITCH, FUSE, AND PLUG-IN UNIT INTERLOCK SWITCH (FIG. 4-2)
CATHODE SUPPLY (MAIN CHASSIS & A1; FIG. 4-7)
DIODE SHAPER BOARD (PROVIDES LOW-VOLTAGE DC FEEDBACK ∝ H. V. OUTPUT) (A13)
HIGH VOLTAGE TRANSFORMER T2
H. V. DC RECTIFIER
REGULATOR TUBES V1-V3
CATHODE SUPPLY CONTROL OPERATIONAL AMPL.
AC LOW-VOLTAGE FEEDBACK CKT (S-F MODE ONLY)
SWEEP RETRACE DISCHARGE CIRCUIT (FIG. 4-8)
- HV OUTPUT TO CATHODE OF MICROWAVE TUBE
TIED TO "0 LINE" IN PLUG-IN UNITS; TIED TO + LEAD OF MICROWAVE TUBE HEATER
VOLTAGE CONTROL SUMMING JUNCTION (CONTROLS H. V. OUTPUT WHICH CONTROLS OSC. FREQ.)
"SWEEP VOLTAGE" DC CONTROL INPUT
"DC LEVEL" CONTROL INPUT FOR S-F OPN
FROM FREQ. CONTROL CKTS
ANODE SUPPLY (-100 V REF.) (A6; FIG. 4-11)
+ H. V. ANODE SUPPLY
"0 LINE"
FEEDBACK SIGNAL FROM ELEVATED SUPPLY IN PLUG-IN
TO PLUG-IN FOR DRIVING BWO ANODE & GRID OR VTM INJECTOR
-100 V SUPPLY (ZENER CONTROLLED) (A6; FIG. 4-12)
-100 V
"0 LINE" FOR H. V. SUPPLIES
LOW VOLTAGE TRANSFORMER T1
+100 V SUPPLY (-15 V REF.) (A2; FIG. 4-5)
TO PCB'S A1, A3, A7 AND PLUG-IN UNIT FOR DRIVING LEVELER CIRCUIT AND BWO COLLECTOR
-50 V SUPPLY (+15 V REF.) (A2; FIG. 4-6)
-50 V
TO PCB'S A1, A3, A5, AND PLUG-IN UNIT
+15 V SUPPLY (-15 V REF.) (A2; FIG. 4-4)
+15 V
TO PCB'S A1, A3, A4, A5, A7; S9, S12, S14, S15, AND PLUG-IN UNIT
-15 V SUPPLY (PRIMARY ZENER CONTROLLED SYSTEM REFERENCE) (A2; FIG. 4-3)
-15 V
TO PCB'S A1, A3, A4, A5, A7; S12, S14, S17; AND PLUG-IN UNIT
POWER SUPPLY GROUND
REFERENCE GROUND
6.3 VAC HEATER OUTPUT FOR CATHODE SUPPLY SERIES REGULATOR TUBES
-6.3 VDC HEATER SUPPLY (A6; FIG. 4-9)
TO MICROWAVE TUBE HEATER
HEATER OVERVOLTAGE SENSOR (A6; FIG. 4-10)
CONTROL SIGNAL TO OVERLOAD INTERLOCKS
18 VAC C. T. HEATER OUTPUT FOR ANODE SUPPLY AND SWEEP DISCHARGE CKT POWER TUBES
NOTES:
1. ABBREVIATIONS:
BWO = BACKWARD-WAVE OSCILLATOR
CKT = CIRCUIT
HV = HIGH VOLTAGE
OPN = OPERATION
OSC = OSCILLATOR
S-F = SINGLE FREQUENCY
VTM = VOLTAGE-TUNED MAGNETRON
WG = WAVEGUIDE
2. "A" NUMBERS IN PARENTHESES REFER TO PC CARDS. FIGURE NUMBERS IN PARENTHESES REFER TO SIMPLIFIED SCHEMATICS IN THIS SECTION.
3 DOTTED BOXES REFER TO COMPONENTS CONTAINED IN THE PLUG-IN. THESE COMPONENTS DIFFER IN THE VARIOUS PLUG-IN UNITS TO MEET INDIVIDUAL MICROWAVE TUBE REQUIREMENTS.
4. ONLY THOSE PANEL CONTROLS IMPORTANT FOR UNDERSTANDING THE OVER-ALL FUNCTIONING ARE SHOWN.

FIGURE 4-1. BLOCK DIAGRAM OF MODEL 650 SERIES
(SHEET 1: POWER SUPPLY CIRCUITS)

SECTION 4

CIRCUIT DESCRIPTION

4.1 BLOCK DIAGRAM DESCRIPTION (See Figure 4-1.)

4.1.1 GENERAL. A Model 650 Series instrument consists of a Model 650 main chassis with 8 PC cards, and an interchangeable Oscillator Plug-in unit with 3 PC cards. The main chassis and its PC cards are identical in every instrument regardless of the plug-in unit(s) used. The PC cards in the different plug-in units are functionally similar but not interchangeable.

The PC cards and their functions are tabulated in Table 4-1 for reference in conjunction with the block diagram description and Figure 4-1.

4.1.2 POWER SUPPLY CIRCUITS. Sheet 1 of Figure 4-1 shows a functional block diagram of the power supply circuits in the Model 650. Input power is applied directly to T1, and through an overload interlock to T2. This interlock removes high voltage power from the microwave tube if the heater voltage rises or if excessive current is collected by the helix of BWO tubes.

The low-voltage supplies are driven by T1. The -15 V supply, which contains a stable, temperature-compensated zener reference, is the primary voltage reference for the system. It is factory-adjusted to provide -15.0000 ± .0075 volts with respect to the common power supply ground, ⑤. A separate, "clean" reference ground, ②, serves as the return for the -15 V supply zener reference diode, and is connected to the ⑤ ground at only one point. The ② ground line is also used as a reference ground for the +15 V supply and certain frequency control and marker potentiometers. The -15 V supply serves as a reference for the +15 V supply and the +100 V supply. The +15 V supply serves as a reference for the -50 V supply.

The + and -15 V supplies are used for transistor bias and frequency control signal reference throughout the instrument. (The frequency control circuits are arranged so that a swing of 0 to +15 V shifts the output frequency across its full range.) The +100 V and -50 V supplies are used to drive biasing networks for cascaded amplifier stages. The +100 V supply provides screen bias for the high voltage regulator tubes in the cathode supply, and drives the collector bias circuit in plug-in units containing a backward wave oscillator tube.

The 6.3 V dc heater supply drives the microwave tube heater. The regulator tube heaters are supplied with low-voltage ac; the V1, V2 and V3 heaters operate on 6.3 V from T1: 5-6, and the V4 and V5 heaters operate on 9 V from T1: 15-16 and T1: 16-17 respectively. The 6.3 V dc heater supply output is monitored by the heater overvoltage sensor.

The high-voltage supplies are driven by T2. The -100 V supply serves as a reference for the anode supply, and also drives the grid bias circuit in the plug-in unit elevated supply for BWO's. The anode supply output level is controlled by feedback from the elevated supply in the plug-in unit and varies from +30 V to +280 V depending upon the plug-in unit used. The anode supply output drives the anode bias circuit of BWO plug-in units and the injector bias circuit of VTM plug-in units. (The VTM anode operates at ground potential.) The return line of both the anode and -100 V supplies is denoted as the "0 line," and it is ground-referenced only through the cathode supply. In BWO plug-in units the cathode supply negative high-voltage output is tied to the "0 line" thus placing the grid bias (-100 V supply) below cathode potential. In VTM plug-in units, since no grid bias is needed, the cathode supply is instead tied to the -100 V output line. This raises the "0 line" 100 V above cathode potential, thereby adding 100 V to the + anode supply output level relative to the cathode, bringing it to the level required for biasing and modulation of the VTM injector.

The cathode supply is a high voltage dc supply in which the output level is controlled by an operational amplifier which drives the series regulator tubes. The input signals to the operational amplifier consist of currents derived from low-voltage positive control signals from the frequency control circuits in the main chassis and low-voltage negative dc feedback from the diode shaper board in the plug-in unit. These currents are summed at the operational amplifier summing junction.

All control and feedback signals are applied to the summing junction through 15 K. The frequency control circuits are arranged so that 0 V is applied across 15 K to the summing junction for frequency output at the low end of the band, and +15 V is applied across 15 K for frequency output at the high end of the band. The control voltage range is linear with frequency in between. Thus, a control signal varying linearly from 0 to 1 ma is supplied to the summing junction for full-range frequency control. The negative feedback through the diode shaper board supplies an opposing current to the summing junction that exactly cancels the control current when the cathode supply output voltage is correct to produce the selected output frequency for the tube in use.

Through proper arrangement of feedback, the cathode supply output can be controlled over a range as great as -150 V to -2500 V in response to control signals of between 0 and +15 V. For single-frequency operation, where a constant output voltage is required, negative ac feedback is applied to the summing junction through a low-voltage converting network to stabilize the output.

For swept operation, a low-voltage sweep is applied across 15 K to the summing junction, and the output is swept from a low negative voltage to a high negative voltage. To permit rapid discharge of the cathode supply output capacitance when the voltage must suddenly drop from a high to low negative value during sweep retrace, a self-triggering sweep discharge circuit is used to shunt the output capacitance.

4.1.3 FREQUENCY CONTROL, MODULATION AND RF OUTPUT CIRCUITS. Sheet 2 of Figure 4-1 shows a functional block diagram of these circuits. The sweep generator produces a control voltage ramp of 0 to 40 V with a slope established by the SWEEP TIME control. Successive sweeps are triggered automatically or by some other signal as selected by the SWEEP TRIGGER selector. The sweep generator also produces a ground-level retrace blanking signal during the sweep retrace and continuing through the "dead" interval before the next triggered sweep.

The sweep output circuit provides load buffering for the sweep

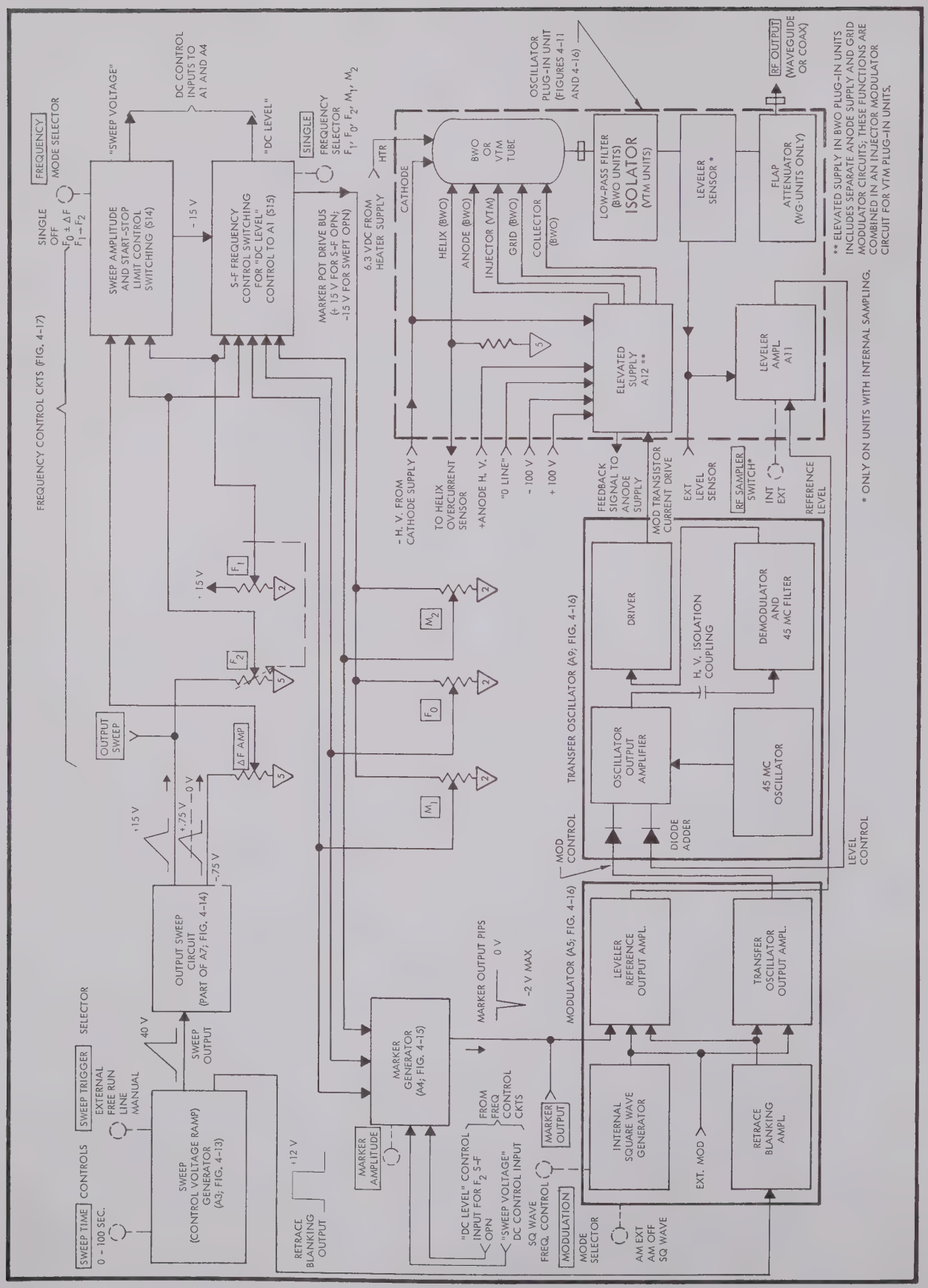


FIGURE 4-1. BLOCK DIAGRAM OF MODEL 650 SERIES
(SHEET 2: FREQUENCY CONTROL, MODULATION, AND RF OUTPUT CIRCUITS)

generator. It supplies a 0 to +15 V ramp output to drive the $F_1 \rightarrow F_2$ sweep frequency control circuits and a zero-centered -0.75 to +0.75 V ramp output to drive the $F_0 \pm \Delta F$ sweep frequency control circuits.

The frequency control circuits include the five FREQUENCY and MARKER potentiometers (F_1, F_0, F_2, M_1, and M_2), the FREQUENCY Mode Selector switch S14, and the SINGLE Frequency Selector switch S15. These circuits produce the various swept and single-frequency modes as follows:

a. For $F_1 \rightarrow F_2$ swept frequency operation, the F_1 potentiometer output is connected to the "dc level" input to the cathode supply summing junction to provide a minimum-frequency starting point for the sweep. For connection to the "sweep voltage" dc control input of the cathode supply, a portion of the 0 to +15 V sweep ramp output corresponding to the frequency increment ($F_2 - F_1$) is obtained from the F_2 potentiometer. This is the voltage increment required to add to the F_1 potentiometer output to obtain a maximum control signal corresponding to F_2 at sweep end. This output from F_2 is obtained by a differential potentiometer drive arrangement where the F_2 knob controls the F_2 potentiometer wiper while the F_1 knob rotates the F_2 potentiometer body in the reverse direction, to subtract an amount equivalent to the F_1 setting from the F_2 wiper output.

b. For $F_0 \pm \Delta F$ swept operation, the F_0 potentiometer output is connected to the "dc level" summing junction input, and a reduced-level, zero-centered sweep from the ΔF potentiometer is applied to the "sweep voltage" dc control input.

c. For the OFF mode, the sweep generator is disabled and held at 0 V output. The resultant retrace blanking output signal is connected to the modulator to turn off the RF output.

d. For single-frequency modes, the output from the selected control potentiometer is applied to the "dc level" summing junction input, with no signal applied to the "sweep voltage" input. For this mode of operation, the marker control potentiometers M_1, F_0, M_2 are driven by +15 V supplied by S15, to provide the proper output polarity for frequency control. The F_2 potentiometer is driven by an adjustable voltage of 0 to +15 V supplied by the MANUAL SWEEP control (not shown). The differential control arrangement of the F_2 potentiometer is maintained in single-frequency mode, so that when the F_2 single frequency is selected, the F_1 potentiometer output is connected to the "dc level" summing junction input and the F_2 potentiometer output is connected to the "sweep voltage" summing junction input. The F_2 potentiometer output corresponds to $F_2 - F_1$ when the MANUAL SWEEP control is set to provide a full +15 V to the F_2 potentiometer. Thus, when the F_2 single frequency is selected the output may be manually swept from F_1 to F_2 by use of the MANUAL SWEEP control.

The marker generator is functional only during the swept output modes and the F_2 single-frequency mode (during which manual sweep may be used). It has a separate summing junction for each of the three markers. Each junction receives the same signals applied to the cathode supply summing junction during swept modes, but operates at a higher impedance level to allow isolation between the summing junctions. The three marker control potentiometers, M_1, M_2 and F_0, are driven by -15 V in the swept-frequency modes, supplied by S15. In the $F_0 \pm \Delta F$ swept mode, F_0 is not used as a marker, and receives +15 V to set the sweep center frequency. Each marker generator summing junction detects the null point when the positive frequency control voltages sweep across the negative level set on its marker potentiometer (corresponding to the rf output crossing of the marker frequency). The generator develops a negative-going marker pip signal with adjustable amplitude, which is connected to the output leveler circuit to produce an absorptive pip in the rf output level at each marker frequency during leveled operation. The marker output pulses are available at the front panel MARKER OUTPUT connector for use during unleveled operation.

The modulator circuit controls amplitude modulation of the rf output. It accepts external modulating signals and also generates a square wave signal for internal modulation. The retrace blanking signal from the sweep generator is applied to the modulator through switching circuits (not shown) to achieve output retrace blanking or rf off modes. All amplitude control signals processed by the modulator are split and applied to both the transfer oscillator (for control of the microwave tube) and the leveler-amplifier (to keep it from compensating for desired amplitude modulation). The one exception to this is the marker pulse train. To obtain optimum high-frequency response for narrow pips, the marker pulses are applied directly to the leveler.

The transfer oscillator couples the amplitude-modulation signals to the elevated supply in the plug-in unit. It provides high-voltage isolation between these low-level modulation signals and the tube supply circuits. The dc signals from the modulator and the leveler-amplifier are summed at the input to the transfer oscillator to permit amplitude modulation within a leveled envelope. When leveled operation is not used, the modulator signal alone drives the transfer oscillator. The input signals to the transfer oscillator control the amplitude of the 45-mc signal coupled from the 45-mc oscillator to the demodulator and filter. The high-voltage isolation is provided by capacitive coupling at the input to the demodulator. The driver converts the variable-level demodulator output signal into a current drive for a transistor modulator circuit in the elevated supply of the plug-in unit. This transistor circuit in the plug-in unit controls the voltage applied to the microwave tube modulating electrode.

The plug-in unit is described in detail in the separate manual for each family of plug-in units. The elevated supply PC Board A12 contains networks which combine and adjust the constant outputs of the anode supply and the +100 and -100 V supplies to provide the necessary anode, collector and grid drive for each BWO, or injector drive for each VTM. It also contains a feedback network which sets the output level of the anode supply. Only one active stage is contained in A12, for control electrode bias. It varies the grid (BWO) or injector (VTM) voltage in accordance with the requirements of the tube for "full-on" to "rf off" in response to the output from the transfer oscillator. The diode shaper board A13 supplies the required dc feedback to the cathode supply to permit rf output frequency control with identical linear control signals regardless of tube used. The leveler-amplifier A11 accepts rf level sensor signals from an internal or external sensor, compares them to a reference level, and drives the transfer oscillator or solid-state leveler to make any necessary output level corrections. The "reference level" signal to the leveler is modulated to prevent the leveler from correcting for desired modulation. The marker pulses are applied to the leveler via the "reference level" line to take advantages of the excellent leveler response for producing narrow marker pips.

Table 4-1 Printed Circuit Cards in the Model 650 Series

PC Card Module Number	PC Card Name	Location	Description
A1	Cathode Supply	Main Chassis, Rt. Side	Contains the voltage control operational amplifier which drives the series regulator tubes in the high-voltage cathode supply and the buffer amplifiers which process low-voltage signals applied to the operational amplifier summing junction as a means of controlling the cathode supply voltage. This voltage, in turn, controls oscillator frequency. All high voltage circuit elements are on the main chassis, not on A1.
A2	Low-Voltage Supply	Main Chassis, Rt. Side	Contains referencing and regulator amplifier circuits for the -15 V, +15 V, -50 V, and +100 V supplies. The diode rectifiers and regulator transistors for these supplies are on the main chassis.
A3	Sweep	Main Chassis, Rt. Side	Contains low-voltage sweep generator circuits used to drive the frequency control circuits to obtain sweep mode operation. Also contains trigger amplifier and control circuits for the various sweep triggering modes. Also generates the retrace blanking signal.
A4	Markers	Main Chassis, Rt. Side	Contains circuits which detect when the output frequency sweeps through any preset marker frequency (by comparison of low-voltage control signals), and generates simultaneous marker modulating pulses.
A5	Modulator	Main Chassis, Rt. Side	Contains a square wave generator and amplifier circuits which accept the internal square wave, markers, retrace blanking signals, or external modulation signals. It generates a control signal for the transfer oscillator and a reference signal for the leveler-amplifier in the plug-in unit.
A6	Auxiliary Supply	Main Chassis, Inside Rear	Contains referencing and regulator amplifier circuits for the -100 V supply, the anode supply, and the microwave tube heater supply. Also includes the heater supply overvoltage sensor. The diode rectifiers and regulator transistors and tubes for these supplies are on the main chassis.
A7	Helix Overcurrent	Main Chassis, Inside Front Panel	Contains the helix overcurrent sensor circuit, and the completely independent output sweep circuit which provides buffering between the sweep generator and the frequency control circuits which use the sweep.
A9	Transfer Oscillator	Main Chassis, Left Side	Contains an rf oscillator which has its output amplitude controlled by signals from the modulator and leveler-amplifier. Includes an isolation transformer and an output rf-to-dc converter which drives the elevated supply in the plug-in unit to control tube output amplitude modulation.
A11	Leveler-Amplifier	Plug-in Unit	Contains amplifier circuits which receive a reference level input from the modulator (A5) and signal-level inputs from an internal or external sensor. Develops an output signal which drives the transfer oscillator (A9) in grid-leveled units and the PIN diode leveler in diode-leveled units, to reduce the output level to a constant value across the band.
A12	Elevated Supply	Plug-in Unit	Contains voltage-controlling networks which couple the high-voltage supply outputs to the appropriate electrodes of the microwave tube. Includes an active stage for modulating the grid (BWO) or injector (VTM) voltage in response to dc control signals from the transfer oscillator.
A13	Diode Shaper Board	Plug-in Unit	Contains a diode-resistor network which generates low-voltage feedback from the cathode supply output for application to the control operational amplifier of the supply. In BWO units, the feedback output is a non-linear function of supply output voltage, which compensates for the non-linear V/F characteristic of the tube to allow frequency control with linear signals. In VTM units, the shaper board has fewer components and the feedback is a simple linear signal, since a VTM has a linear response. The PC card also contains a buffer amplifier for the feedback output signal.
A10	Series Regulator/ Retrace Discharge Assembly	Main Chassis, Right Rear	Contains the regulator tubes for the cathode supply (V1 - V3) and the anode supply (V4); and the retrace discharge tube (V5) and associated circuits. Prior to S/N 1051, these components are considered part of the main chassis.
A15	Rectifier Assembly	Main Chassis, top center	Contains the diodes and packaged bridge rectifiers used in all low- and high-voltage supplies. Prior to S/N 1091, these components are incorporated in the main chassis assembly instead of a separate circuit board.

4.2 PRIMARY POWER DISTRIBUTION. (See Figure 4-2.)

The power input through the line cord passes through the main fuse F2 on the rear of the chassis, and through thermistor RT1 which protects against an initial surge of current when the instrument is turned on. From the POWER switch S1, all primary power passes through the plug-in interlock microswitch S2 which is mounted behind the front panel and actuated by the clamp finger of the plug-in unit when it is properly locked in position.

From S2, the power splits into two circuits to drive the low voltage transformer T1 and the high voltage transformer T2. The circuit to T1 is protected by fuse F1 located inside the chassis. The connection to the T1 primary windings is made through 115-230 VAC switch S3 located inside the rear of the chassis. S3 is arranged so that for 115 V operation, the two windings are connected in parallel; while for 230 V operation they are connected in series. Thus in either mode of operation, 115 V power is applied to each winding. The 115 V applied to one winding is used to drive the POWER ON light DS1 and to supply 115 V to the plug-in unit. (This 115 V ac input is used only by the high-power VTM plug-in units with cooling fans and the Power Supply Plug-in Unit Model 650-P1.) The low-voltage outputs from T1 are utilized to drive the low-voltage power supplies and tube heater circuits shown in Figure 4-1.

The primary power to high voltage transformer T2 passes through the protection circuit consisting of relays K1 and K2 and the top and rear panel interlock switches S5 and S6. This circuit is protected by fuse F3 located inside the chassis. The interlock switches are located just behind the removable top and rear cover panels (which permit access to high voltage circuits) so that these panels must be installed to close the switches.

The 60-second time delay relay K1 prevents application of high voltage power until the microwave tube has been warmed up by its heater and the low voltage supplies have had time to stabilize. When the instrument is initially turned on, high voltage relay K2 is de-energized, and its contacts B-1 connect terminal K1-6 to ground, completing the 6.3 V ac circuit through the heater of K1. After 60 seconds, the K1 contact closes, completing the ground return path of the K2 coil. K2 then energizes and completes the primary power circuit for T2 through its contacts A-2. The circuit includes contacts A-1 of protection relay K3, which is normally de-energized. If the protection circuits detect a heater overvoltage or helix overcurrent condition, relay K3 will be energized to remove primary power from T2, thereby disabling the high voltage supply. Operation of the protection circuits to supply +100 V to the K3 coil is described in Paragraphs 4.7 and 4.8. Once K3 has energized, it self-latches through its contacts B2 and the HV RESET button. When S4 is pressed, it allows K3 to de-energize if the overload condition has been corrected.

The connection to the T2 primary coils is made through 115-230 VAC switch S3. The 115 V applied to one winding is tapped to drive the H. V. ON light DS2.

4.3 +15 AND -15 VOLT POWER SUPPLIES. (See Figures 4-3 and 4-4.)

The +15 and -15 volt power supplies provide the low voltage outputs which are used for reference voltages and control circuit power throughout the instrument. The -15 V supply serves as the primary reference, and its primary reference standard is A2CR1, a 1N823A temperature-compensated zener diode.

The -15 V supply consists of a two-stage differential amplifier (dual transistor A2Q8, and A2Q6-A2Q7), a driver (A2Q5), and a series regulator transistor (Q4). The components shown within the dotted border in Figure 4-3 are located on L. V. Supply Circuit Board A2, accessible from the right side of the instrument. The use of metal film resistors in all critical circuits, and matched transistors in the input stage at A2Q8, minimizes noise and drift in this supply. As in all closed-loop feedback systems, tight control of phase response must be maintained. This is accomplished by A2C5 and A2R34 located at the differential amplifier output, the collector of A2Q6.

The feedback loop operates as follows to keep the output constant at -15 volts: If the output should tend to increase negatively to more than -15 V, the forward emitter-base bias on the right half of A2Q8 will increase more than that of the left half. This is because A2CR1 holds the base voltage constant on the right half, while voltage divider A2R17, A2R18, and A2R19 drops the base voltage applied to the left half when the -15 V output drops. The output of the first differential amplifier stage will then couple a more negative signal to the base of A2Q6 than to A2Q7 because of heavier conduction through A2R21. This will, in turn, increase the conduction through A2Q6 which tends to make the base of A2Q5 less negative. The conduction of A2Q5 is reduced, causing its emitter voltage - and therefore the base of the series regulator transistor - also to become less negative.

This action decreases the conduction of regulator transistor Q4 so that it offers greater series resistance in the output line, returning the level to exactly -15 V. If the output should tend to decrease to less than -15 V, the feedback loop will restore the output level by increasing the conduction of Q4. The -15 V output is connected to TP4 on the right side of the instrument. Potentiometer A2R18 permits precision adjustment of the -15 V output by establishing the proper quiescent operating bias for the first differential amplifier stage. Since the -15 V supply serves as primary reference for the instrument, it must be set to -15.0000 V ± 0.0075 V.

The -15 volt supply output is applied to A2R10 in the +15 V supply to serve as a reference for the +15 V supply. Except for the reference circuit, the +15 V supply circuitry is functionally identical to the -15 V supply. A2Q4 is the dual matched transistor first differential amplifier stage, A2Q2 and A2Q3 constitute the second differential amplifier stage, and Q3 is the series regulator transistor.

The components of the +15 V supply shown within the dotted border in Figure 4-4 are also contained on L. V. Supply circuit board A2. Potentiometer A2R9 in the reference string between the -15 V reference and the +15 V supply output provides for adjustment of the differential amplifier reference to obtain exactly +15 V output from the supply. The main phase response control is provided by A2C2 and A2R5 across the collectors of A2Q4. The +15 V output is connected to TP2.

4.4 +100 AND -50 VOLT POWER SUPPLIES. (See Figures 4-5 and 4-6.)

In addition to the +15 and -15 volt supplies there are two other low-voltage sources: the +100 and -50 V power supplies. The +100 V supply consists of a single stage differential amplifier, A2Q9 and A2Q10, which controls a driver stage, A9Q13, that drives the series regulator transistor Q1. A neon bulb, DS3, protects Q1 during turn-on. The +100 V supply uses the -15 V supply as a reference.

The -50 V supply consists of an amplifier (A2Q12), a driver (A2Q11), and a series regulator transistor (Q2). The +15 V

supply serves as the reference for this supply. Phase response is controlled in the driver stage by means of A2C10 and A2R37. Diode A2CR2 provides temperature compensation and diode A2CR3 prevents transients from damaging A2Q12.

Components shown within the dotted border in Figures 4-5 and 4-6 are contained on the L. V. Supply circuit Board A2 along with the + and -15 volt supply components. The +100 V and -50 V supply outputs are brought out to TP1 and TP5, respectively, on the right side of the instrument.

4.5 CATHODE SUPPLY. (See Figure 4-7.)

4.5.1 GENERAL. The cathode supply provides adjustable high voltage to drive the cathode of the microwave tube and permit voltage-tuning of the rf output frequency. The supply contains a solid-state operational amplifier which drives the series regulator tubes. It provides an output voltage in the kilovolt range which is varied in accordance with low-voltage tuning control signals applied from the control circuits. The control voltages are developed from constant-impedance sources and converted to currents by summing resistors that couple them to the amplifier input summing junction. There, they are summed with a dc feedback signal derived from the supply output to reduce the summing junction current to zero when the amplifier generates the correct high-level output voltage to operate the microwave tube at the desired frequency.

Because the tuning curve of a backward wave oscillator (BWO) tube is non-linear, the output of the cathode supply for BWO plug-in units must vary in a non-linear fashion with respect to the linear input control signals. This is necessary to achieve an output frequency directly proportional to the control signals which vary linearly with frequency. Conversely, the voltage/magnetic-field/frequency relationship of a voltage-tuned magnetron (VTM) is linear, and the output of the cathode supply for VTM plug-in units must vary in a direct linear ratio with the input signals.

To accomplish this variation in cathode supply output characteristics versus frequency for different plug-in units, the dc feedback signal from the supply output is derived in a Diode Shaper Board (A13) located in the plug-in unit. A different A13 board is used with each different tube. Other components of the cathode supply are standard and are contained in the Model 650 chassis. In addition to providing output shaping for the cathode supply voltage, the Diode Shaper Board also provides adjustments for the absolute voltage level at each end of the tuning range, to allow setting the proper over-all slope and voltage calibration for the linear or non-linear supply output, to meet the exact requirements of each tube.

4.5.2 OPERATIONAL AMPLIFIER AND SUMMING JUNCTION. The cathode supply operational amplifier consists of three differential stages and an emitter follower. A1Q1 is the input or first stage, A1Q2 and A1Q3 constitute the second stage, and A1Q4, A1Q5 and A1Q6 make up the third stage. The operational amplifier output stage is A1Q7, an emitter follower which drives the grids of the high voltage series regulator tubes V1, V2 and V3. These tubes are operated in parallel to control the output voltage of the supply. They are connected between the + side of the full-wave high voltage rectifier and ground, so that the voltage drop across the tubes reduces the effective high-voltage output level.

Resistors A1R8 and A1R12 are placed across the collectors of the first two differential stages to establish an amplifier gain independent of transistor parameters. The primary phase response of the amplifier is determined by A1C6 and A1R15 at the collector of A1Q6. A1CR1, at the base of A1Q7, is a 75-volt zener diode which changes the amplifier output dc voltage level at the collector of A1Q6 from about +50 volts to approximately -25 volts, to operate the grid driver emitter follower below power supply ground, as required by the grids of V1-V3.

All signal inputs to the operational amplifier are applied to the input summing junction as currents from high-impedance sources. The operational amplifier drives the cathode supply to maximum output voltage when the sum of the control signal input currents is 1 ma,in order to provide maximum negative feedback current to reduce the net summing junction current to zero. The control circuits are arranged to supply this maximum input when set for the signal output frequency at the high end of the band. The negative dc feedback current produced by the Diode Shaper board balances the control current when the output voltage reaches the required high-frequency voltage drive, as preset for the particular tube in use. The operational amplifier drives the cathode supply to its minimum output voltage when the sum of the control signal input currents to its input summing junction is 0. This output voltage corresponds to the low-frequency voltage drive point selected by an adjustment on the Diode Shaper Board, at which point the net feedback current it generates drops to zero. Thus, the net summing junction current is reduced to zero at that level of voltage output, and no further reduction in voltage takes place. The control circuits are arranged to supply zero input current when set for the frequency at the low end of the band. For all in-between frequencies, the control signal input varies linearly from 0 to 1 ma, and the diode shaper board provides feedback to exactly cancel the control signal when the proper high-voltage output level is reached.

There are four primary inputs to the summing junction: two control signals and two feedback signals. These are shown in heavy lines in Figure 4-7. Secondary balancing and external frequency control signals are shown in light lines. The two feedback signals are the dc feedback, which controls the output voltage level as described above, and an ac feedback to reduce ripple and noise on the supply when the oscillator tube is operating at a single frequency without modulation.

4.5.3 FEEDBACK SIGNALS TO SUMMING JUNCTION. The ac feedback circuit consists of C16, a 0.005 μf, 6000 volt capacitor located on the main chassis, and a two-stage current amplifier A1Q8 and A1Q9 on the Cathode Supply PC Board A1. Diodes A1CR2 and A1CR3 clip transients of either polarity to prevent overload damage to A1Q8. The ac feedback amplifier serves as an impedance converter, receiving its input as a voltage ripple on the high-impedance cathode supply output, and providing a low-impedance current drive signal to the summing junction. The amplifier output, from emitter follower A1Q9, is fed through the necessary front-panel switching to terminal W of PC Board A1 and then to the summing junction input of the operational amplifier. Switches S12A and S14M remove the ac feedback when the instrument is operating with a swept or modulated output signal. S12A and S14M connect the ac feedback to the summing junction only when the instrument is in the single-frequency operating mode with amplitude modulation off. This feedback drives the summing junction to correct any fluctuations in the steady-state output voltage.

For plug-in units using BWO tubes, the dc feedback, which controls the cathode supply output voltage, is derived from feedback resistors R1 through R6 in the plug-in and resistors A13R1 through A13R11 on the Diode Shaper Board A13, also in the plug-in. The voltage from this divider is applied to a two-stage current amplifier A13Q1 and A13Q2. The output of A13Q2 is fed through two temperature-compensating silicon

diodes, A13CR13 and A13CR14, to terminal Z on PC Board A1 and then to the summing junction input of the operational amplifier. The shaper diode-resistor network consisting of A13CR1 through A13CR10 and A13R3 through A13R11 provides the required non-linear feedback arrangement by forming a curve from ten straight-line segments.

This network operates as follows: Resistor A13R2 is connected across the feedback path, and is progressively shunted by resistors A13R3 through A13R11 as the feedback voltage level increases (negatively) to the point where each successive diode is brought into conduction. This occurs when the feedback voltage level at A13R2 drops below the anode bias level of each diode, as derived from the resistor string A13R15 - A13R24 connected across the + and -15 V supply lines. This progressive shunting away of feedback current produces an increase in the slope of the output voltage with a constant input control voltage slope, so that the output voltage will rise in a non-linear fashion with respect to the input voltage.

Resistor A13R1, the "Start Frequency Adjust" control, sets the minimum supply output voltage (corresponding to low-end-of-band operation). It injects a fixed minimum positive input current into the feedback system to produce the supply output level that generates a cancelling negative feedback signal when the control signal input is 0. Resistor A13R28, the "End Frequency Adjust" control, is set to achieve the appropriate feedback level for the output voltage required at the high end of the band, when R2 is fully shunted by the shaper network.

For plug-in units using VTM tubes, the Diode Shaper Board A13 is simpler, as shown on the apron of Figure 4-7, since it does not have to supply a non-linear feedback function. The dc feedback, which again controls the cathode supply voltage, is derived from resistors R1 through R6 in the plug-in and applied directly through terminal F of A13 to the two-stage current amplifier, consisting of matched dual transistor A13Q1. The output of A13Q1 is fed through two temperature-compensating silicon diodes, A13CR2 and A13CR3, to terminal Z on PC Board A1 and then to the summing point input of the operational amplifier. In this circuit, the "Start Frequency Adjust" control A13R5 sets the conduction of A13Q2 to inject a positive feedback current to produce the desired minimum output voltage. The "End Frequency Adjust" control A13R8 sets the feedback level to achieve the proper maximum output voltage.

The "Max Cal" control A1R38 on the cathode supply PC board provides an adjustment independent of the Diode Shaper board, to standardize amplifier and regulator gain with respect to the feedback loop.

4.5.4 CONTROL SIGNAL INPUTS TO SUMMING JUNCTION. The two primary control signal currents fed to the summing point are derived from the "dc level" input and the "sweep voltage." The "dc level" input is used for the sweep start-frequency voltage input and also for the single-frequency and symmetrical sweep center-frequency (F_0) voltage input. The signal applied to this input is determined by the front panel control switching.

For $F_1 \rightarrow F_2$ sweep operation, the positive sweep voltage input, a sawtooth with an amplitude proportional to the selected top frequency (F_2), is added to the start frequency voltage (proportional to F_1). For $F_0 \pm \Delta F$ sweep operation, a sawtooth centered on 0 volts with an overall amplitude proportional to $2\Delta F$ is added to the center frequency voltage proportional to F_0. Thus, the negative portion of the sawtooth sweeps the frequency below F_0 and the positive portion sweeps it above F_0.

The primary control signal inputs are impedance-converted to drive the summing junction through 15 K as constant-current sources. The impedance converter circuit utilizes a form of operational amplifier known as the voltage follower, in order to reduce the resultant loading on the panel control potentiometers in the dial assembly. The voltage followers consist of A1Q10 and A1Q12 on the "dc level" input, and A1Q11 and A1Q13 on the "sweep voltage" input. These amplifiers characteristically offer a very high input impedance while maintaining a very low output impedance for summing point drive. They do not invert the signal. Signal voltages for the marker circuits are also taken from the outputs of the voltage followers, to furnish frequency-related marker circuit drive without loading the panel control potentiometers.

There are two additional input signals fed to the summing point, the external fm input and the balance input. The balance input is set by "Balance" control A1R24, and is used to balance the emitter-to-base voltage of the input transistor pair A1Q1.

The external fm input permits control of output frequency with a remote low-voltage source. The dc input resistance of the external fm input is 15 K. Thus, 15 V will produce maximum signal input current of 1 ma and, therefore, the maximum frequency.

CAUTION: When using external frequency modulation, the external signal is added to the signals from the panel controls. Be careful to avoid a summing junction current in excess of 1 ma. For example, when the frequency is set to a mid-scale value (50 on the logging scale) using the panel F_0 control, the maximum dc or peak ac voltage at the FM INPUT jack must not exceed 7.5 volts. This will result in 0.5 ma through A1R5, which will add to the 0.5 ma through A1R3 from the mid-scale "dc level" input to produce 1 ma junction current.

4.5.5 OUTPUT CONNECTIONS. The "0 line" used as a reference point in other high voltage dc supplies and circuits is tied directly to the cathode supply output in all Plug-in units, by a connection within the Plug-in unit. With BWO tubes, the grid must be operated at a negative voltage with respect to the cathode. Since the "0 line" is the return line for the -100 V supply, the -100 V supply output, which is used for biasing the grid, is more negative than cathode potential. For VTM tubes, the cathode bias is the most negative voltage required, while the VTM injector (which is operated by the anode supply used for BWO anodes) requires a higher positive voltage than does a BWO anode. The basic range of the anode supply, which uses the "0 line" as a return, is sufficient for both tube types.

4.5.6 SWEEP RETRACE DISCHARGE CIRCUIT. (See Figure 4-8.) The cathode supply output is capacitively loaded by C14 and other stray circuit capacitance. To permit rapid discharge of the supply output capacitance during sweep retrace when the output rapidly drops from the maximum to the minimum negative voltage, a sweep retrace discharge circuit is used. This circuit, shown in Figure 4-8, consists of high voltage beam pentode V5 and control transistor Q6 and Q7.

During retrace, the cathode supply output voltage tries to become less negative very rapidly, and the rate of change is limited by the rate at which C14 can be discharged into the load. Tube V5 is brought into conduction during retrace only, to

quickly discharge C14 by completing a circuit through R52 and R56. The connection of the cathode supply in plug-in units as shown in Figure 4-8, places C9B in the C14 discharge path through V5. Since C9B has about 400 times the capacity of C14, it is not significantly affected by the current flow required to discharge C14.

During the sweep, V5 is cut off by its low grid voltage, produced by the lack of current through Q7 which is biased to cutoff due to the strong conduction of Q6, which drops the junction of R55 and R57 to ≈-100 V. Q6 is biased to strong conduction by the reverse leakage current through CR19. When retrace begins, the discharge current of C15, through R58, produces a large voltage drop which bucks out the voltage that was forcing a reverse current through CR19. This eliminates the positive base bias and cuts off Q6, thereby raising its collector voltage toward 0-line potential. The resultant increase in voltage across R57, which then acts as a voltage divider across 100 V with R55, brings Q7 into conduction, turning on V5. When retrace ends, the elimination of the C15 discharge current through R58 again allows Q6 to turn on, eliminating the bias across R57 and thereby cutting off Q7 and V5. R52 provides a convenient low-voltage monitoring point for the sweep discharge current.

4.6 HEATER SUPPLY. (See Figure 4-9.)

The heater supply for the microwave oscillator tube is a regulated dc supply using a series regulator transistor and a two-stage transistor amplifier. The heater supply control amplifier consists of A6Q6 and A6Q7, mounted on the A6 PC board, and series regulator transistor Q5 mounted in the main frame. The reference voltage is supplied as a fixed offset from the output level by zener diode A6CR3. This diode is connected to J7-12 at the connection to the plug-in unit, so that voltage sensing will take place as close as possible to the load. The A6Q7 emitter bias resistor A6R18 is returned to a constant -5.6 V developed across A6CR10 by rectifier diodes CR21 and CR22. This provides the necessary biasing configuration for the direct-coupled amplifier stages A6Q6 and A6Q7. The amplifier input is provided by the difference between the output sample applied to the base of A6Q7 from A6R21, and the reference level (5.6 V below output level) developed at the emitter of A6Q7 by A6CR3. The heater voltage is set to 6.3 V at nominal line voltage, by adjusting A6R21 when 1 ampere of heater current is being supplied.

For plug-in units using BWO tubes, the heater supply output is connected directly to the BWO heater through connections in Elevated Supply PC Board A12. The high voltage cathode supply is tied to the + output terminal of the heater supply within A12, so that the heater operates at a negative potential with respect to the cathode.

For plug-in units using VTM tubes, the heater supply output voltage is applied to a post-regulator amplifier circuit which regulates the current that flows through the VTM heater from the fixed-voltage supply. This current-regulating amplifier circuit is shown on the apron of Figure 4-9. It consists of input filter C2, and self-biased amplifier Q3-Q4. Q4 is connected in series with the VTM heater, so that its collector-to-emitter resistance combines with the heater resistance to establish the total current flow with the fixed-voltage drive. Since the voltage is maintained constant at 6.3 V by the regulator amplifier in PC Board A6, the current regulating amplifier in the plug-in can adjust the VTM heater current to any desired level by biasing Q4 to the proper conduction point. The conduction of Q3 and Q4 is set with "Heater Current" control R30. In the VTM tubes, the cathode and + heater terminal are internally connected. These two supply lines are connected within A12.

4.7 HEATER OVERVOLTAGE PROTECTION CIRCUIT. (See Figure 4-10.)

Transistor A6Q8, and its associated circuitry on Auxiliary Supply PC Board A6, form an overvoltage sensing and trip-out circuit. This circuit energizes relay A6K1 (Figure 4-10) to remove the voltage from the microwave tube heater if it rises to above 7 V. It also energizes relay K3 in the primary power distribution circuit (Figure 4-2) to turn off all high voltage power.

The positive output from the heater supply is applied to the tube through the contacts of relay A6K1. A coil of this relay is energized by transistor A6Q8 which is normally non-conducting. In order for A6Q8 to conduct, the voltage drop across A6R22 must exceed 1.3 V. This is the voltage drop across the base-emitter junction of A6Q8 plus the voltage drop across A6CR5. Diode A6CR4 is a 5.6 V zener and is connected in series with A6R22 across the 6.3 V heater supply. Thus, it will be necessary for the heater voltage to go to 6.9 V before the voltage drop across A6R22 will be the necessary 1.3 V to cause conduction in A6Q8. If this condition exists, then A6Q8 will conduct and will energize relay K1 which disconnects the heater supply from the oscillator tube heater. The other fixed contact on relay K1 will then apply the full unregulated heater supply voltage to the series combination of A6R24, A6DS2 and the light bulb in the photocell assembly A6A1. The light from this bulb illuminates photocell 4403 and causes its resistance to drop to a very low value. This applies +100 V to the high voltage trip-out relay, K3 (Figure 4-2) which then energizes and disconnects all high voltages in the unit. Lamp A6DS2 also glows to provide a visible indication of heater overvoltage trip-out.

4.8 HELIX OVERCURRENT PROTECTION CIRCUIT. (See Figure 4-10.)

The helix overcurrent circuit is functional only when BWO plug-in units are used. It provides protection for the backward wave oscillator tube by operating relay K3 in the primary power distribution circuit to turn off all high voltages to the tube should the helix current rise above a preset maximum level. This level is given in the plug-in unit instruction manual. This circuit consists of A7Q1, A7Q2, A7Q3, and A7K1 on the Helix Overcurrent PC Board, A7, which is mounted on the back of the front panel of the instrument. The circuit consists of a differential amplifier stage (A7Q2 and A7Q3) and a relay drive stage (A7Q1). The base of A7Q2 is connected directly to ground. The base of A7Q3 is connected to ground through A7R14, which shunts the helix current bleeder resistor A12R2 in the plug-in and therefore carries part of the helix current.

With no helix current flowing, the differential amplifier stage is balanced so that the relay control transistor A7Q1 draws sufficient current to keep relay A7K1 energized. The balance control for the differential amplifier is A7R3. If the current through A7R14 exceeds 1 milliampere, the increased conduction through A7Q3 robs current from A7Q2, and the resultant decreased conduction through A7Q2 causes the relay control transistor A7Q1 to reduce its current sufficiently to de-energize relay A7K1. This applies +100 V dc through the normally closed contacts of A7K1 to the high voltage interlock relay K3 in the main chassis (Figure 4-2). K3 then energizes, opening the circuit to the primary of the high voltage transformer and thereby removing all high voltages from the oscillator tube. K3 is self-latching and keeps the high voltage turned off until the RESET button on the front panel of the instrument is depressed.

4.9 ANODE SUPPLY. (See Figure 4-11.)

The anode supply provides power for the anode of BWO tubes and for the injector of VTM's. Each plug-in incorporates differences in wiring and voltage adjustment networks to provide the correct voltage to the proper tube electrode. The anode supply circuit consists of a full wave rectifier and regulator tube V4 which shunts the supply output resistors to provide output voltage control over a range from about 350 volts (tube cut off) down to about 25 volts (tube heavily conducting). The regulator tube is controlled by a regulator amplifier contained on part of Auxiliary Supply PC Board A6, and which consists of a differential input stage (A6Q10 - A6Q11) and output emitter follower driver stage A6Q9.

Since both the BWO anode and VTM injector require a voltage which is positive with respect to the cathode, the negative terminal of the anode supply is tied to the "0 line" which is referenced to the high-voltage cathode supply output line as shown in Figure 4-7.

The resistors which set the amount of feedback applied to the regulator amplifier, and thereby control the anode supply output voltage, are contained in the Elevated Supply PC Board (A12) in the plug-in unit. A different A12 board and/or different resistors on the board are used for each different tube. The -100 V supply is used as a reference for the voltage control network in A12 and also as the emitter bias return for the regulator amplifier in A6. Diodes A6CR7 and A6CR8 connected across the bases of the differential stage are transient-protecting diodes which prevent damage to the input transistors in the event of malfunction. Diode A6CR6 provides bias for the emitter of A6Q9. Capacitor A6C5 with resistor A6R30 provides both ac feedback to reduce the ripple on the supply, and phase stabilization to prevent oscillations.

In BWO tubes, the anode is located in the gun structure to collimate the electron beam before it is accelerated to helix potential. The anode positive potential required may vary from 30 to 280 volts depending upon tube type. The portion of Board A12 controlling the anode supply output voltage in BWO plug-in units is shown in Figure 4-11. The voltage control network consists of "Anode Adjust" resistor A12R9 and A12R10 on the reference side and A12R11 and A12R14 on the feedback side. A12R9 is set to the point where the reference voltage supplied through it just balances the feedback voltage at the desired output level. The 50 K value of A12R9 is selected to provide high resolution. Since this low value (compared to A12R10) restricts the voltage adjustment range provided by A12R9, the feedback circuit is matched to the center adjustment point of A12R9 for the voltage required for each tube, by factory-selecting A12R14. To cover the full voltage range of the supply (30 to 280 volts), resistor A12R14 is selected from a table of values ranging from approximately 90 K ohms to 750 K ohms. This table is shown graphically in Figure 5-8.

The VTM's used instead of BWO tubes in some plug-in units of the 650 Series operate with the anode in direct electrical contact with the output circuit. Thus, the VTM tube is operated with the anode at chassis potential and with negative cathode drive. These VTM tubes utilize an electron injector design which acts to accelerate and control the flow of electrons from the hot cathode to the interaction space, minimizing back-bombardment of the indirectly heated cathode. This provides long life and minimum output power variation across the tuning range by reducing the cathode current variation resulting from cathode-anode voltage fluctuations. The positive potential required for the injector may vary up to 200 V with respect to the cathode, depending upon tube type. Since the cathode supply is tied to the "0-line" in VTM plug-in units, the -100 V supply permits the injector voltage to be dropped to -80 V to shut off the tube when injector modulation is used. The "anode supply" control circuit on PC Board A12 used in VTM plug-in units sets the supply output to provide the necessary positive injector drive. The control circuit for VTM plug-in units is shown on the apron of Figure 4-11. This circuit is integrated with the injector modulator circuits, since in VTM's there is no "grid" electrode for modulation. The VTM plug-in units use the PIN diode attenuator to control output level for modulation and leveling applications, but an injector modulation mode is selectable to provide 100% rf turn off.

The dc level control network used is similar to the BWO circuit, with A12R5 and A12R6 constituting the reference side and A12R12/A12R14 and A12R7 making up the feedback side. The values of A12R12 and A12R14 are factory-selected to place the output voltage within the limited, high-resolution control range of A12R5.

Transistor A12Q1 shunts the regulated output voltage supplied to the injector by an amount which varies under control of the injector driver and amplitude modulator circuits. As conduction of A12Q1 is increased by these modulation control circuits, the increased current through A12R1 drops the output voltage supplied to the injector via terminal 11 of A12. Thus, the applied injector voltage can be varied as required for modulation purposes by application of proper signals to terminal 1 of A12. (For BWO tubes, modulation is accomplished by controlling the grid which is independent of the anode supply voltage.)

In both BWO and VTM plug-in units, a diode-resistor network is used to improve the initial control response of the regulator amplifier when the instrument is turned on. At turn-on, little current flows through A6R25 so that the -100 V from the transistorized -100 V supply biases the grid of V4 to prevent conduction. The forward drop across A6CR7 is such that A6Q10 receives a stronger base drive from the voltage divider A6R26-A6R27, and it takes control of the differential stage, cutting off A6Q11. Until A6Q11 turns on, A6Q9 cannot be turned on to bring V4 into conduction to regulate the output voltage. As C8B is charged to the required level, the output across the bias string in the plug-in unit rises to the point where A6Q11 is biased to take control and turn on V4. Diode A12CR2 (CR1 in VTM units) clamps the junction of A12R14 and A12R11 (R7 in VTM units) to the 0-line, to place a limit on the positive supply output excursion. This prevents the overshoot that would otherwise occur if less current were drawn from C8B through A12R14 during the turn-on delay time of V4.

4.10 -100 VOLT SUPPLY. (See Figure 4-12.)

The -100 V supply furnishes power to the elevated supply in the plug-in for use in the grid control amplifier of BWO units and for the anode supply feedback network in all units. It also serves as a reference voltage for the anode supply and provides power to the transfer oscillator output stage. The -100 V supply uses a two-stage transistor differential amplifier (A6Q4-A6Q5 and A6Q2-A6Q3) to drive the series regulator transistor A6Q1. The reference voltage for this supply is derived from A6CR2, a 1N823 temperature-compensated zener diode. The zener voltage is compared to a portion of the -100 V output tapped from A6R5, in the input differential stage (A6Q4 and A6Q5). The output of this stage is applied to the second differential stage (A6Q2 and A6Q3). The output of the second differential stage is taken from the collector of A6Q2 and applied to the base of A6Q1, the series regulator transistor.

Neon bulb A6DS1 protects A6Q1 during the turn-on transient. Capacitor A6C3 and resistor A6R11, across the collectors of the input differential stage, provide the major phase correction for this amplifier. Capacitor A6C1, with resistor A6R8, provides ac feedback to reduce ripple and noise at the output of this supply. Diode A6CR1 connected to the base of A6Q4 provides a discharge current path for the feedback capacitor A6C1.

Since this supply is used as a reference for the anode supply, it is necessary that the voltage be set and regulated to 100.0 V ± 0.1 V. The positive terminal of this supply is tied to the "0 line," since the BWO grid must be biased negatively with respect to the cathode, and since the anode supply is also tied to the "0 line." The supply output is filtered by C9B.

4.11 SWEEP GENERATOR. (See Figure 4-13.)

The sweep generator consists of four major circuits contained on Sweep PC Board (A3):

a. The ramp generator - an operational integrator.

b. The retrigger multivibrator - a multivibrator circuit.

c. The retrigger delay - a modified Schmitt circuit.

d. The trigger generator circuit which includes the trigger hold-off amplifier.

The ramp generator includes transistors A3Q4, A3Q5, A3Q6 and A3Q7, connected in cascade to form a high-gain operational amplifier, and integrating (feedback) capacitors A7C1 through A7C4 selected individually by the SWEEP TIME switch S11. The input resistance is supplied by R31 and Sweep Time Vernier control potentiometer R30. The input stage is a silicon transistor A3Q4 operating at a collector current of approximately 10 microamperes. This will hold the input base current, obtained from the -15 V supply, to an absolute minimum. The second stage is an emitter follower, A3Q5, which minimizes the loading on the high collector impedance of the first stage. The third stage A3Q6 is a low-gain amplifier used for isolation of the high emitter impedance of the second stage. The fourth stage A3Q7 is a current amplifier whose collector load is R33, a 2.5 K ohm resistor connected to the +100 V supply. Resistor A3R44 reduces the power dissipation in A3Q7. The collector output signal of A3Q7 is fed back to the input of A3Q4 through one of the four feedback capacitors, selected for the desired integrating time constant. This output signal is a 40 volt ramp which is connected to terminal R. The ramp runs linearly from 0 to +40 V. When +40 V is reached, the retrigger multivibrator and retrigger delay process a pulse to reverse the current polarity at the operational amplifier input and quickly drive the sweep output back to zero. The 40 V sweep is connected to the trigger generator through A3R17, and to the retrigger multivibrator through A3R8 and diode A3CR2. A3R8 and A3R7 constitute a voltage divider which is connected to -15 V, to provide a zero crossover in the ramp output to the retrigger multivibrator. Diode A3CR2 is connected between the junction of A3R8 and A3R7 to convert the zero crossover into a pulse-type drive for the retrigger multivibrator.

The retrigger multivibrator consists of A3Q1 and A3Q2. When the voltage at the output of the ramp generator reaches approximately +41 V, A3CR2 conducts and a positive pulse is applied to the base of A3Q2. This causes the multivibrator to switch stages (A3Q2 conducting and A3Q1 non-conducting). The resultant positive voltage at the collector of A3Q1 is fed through resistor A3R37 and diode A3CR6 to charge capacitor A3C10. This positive voltage is also fed through emitter follower A3Q14 and then to the input of the "retrigger delay" Schmitt trigger (A3Q13 - A3Q12). A positive step function voltage appears at the collector of A3Q12 and is fed through A3R13 and A3CR3 to the input of the ramp generator. This positive voltage swamps out the negative input through R30 and R31, and since the ramp generator now sees a positive rather than a negative input current, its output reverses direction and the sweep retrace begins. The retrace time is determined by the magnitude of the input current which, in turn, is determined by the value of A3R13 and the sweep retrace time resistors A7R11 and A7R12 which are connected in various shunt combinations by the SWEEP TIME switch S11. A3R13 is used alone in the .01 and .1 second sweep positions, shunted by A7R12 in the 1 second position, and shunted by A7R11 in the 10 second sweep position. The values of A3R13, A7R11 and A7R12 are selected so that the retrace time in the 10 milliseconds sweep position is approximately 2 milliseconds; in the 100 millisecond sweep position, approximately 20 milliseconds; in the 1 second sweep position, approximately 80 milliseconds; and in the 10 second sweep position, approximately 800 milliseconds. When the output voltage from the sweep generator reaches zero volts, diode A3CR7, connected between the input and output of the operational integrator, will conduct. This conduction effectively ties the input and output of the amplifier together and stops any further voltage decrease at the output terminal.

The output remains at 0 volts during a delay interval and until the next sweep ramp is triggered. The method of triggering differs with the setting of the SWEEP TRIGGER selector switch S10. In the FREE RUN sweep position, the 40 V sweep is fed through A7R15 back to diode A3CR1 and to the input of the retrigger multivibrator. This will reset the retrigger multivibrator by applying a negative pulse to the base of A3Q2 when the 40 V sweep is retraced to 0 volts (leaving A3Q2 non-conducting and A3Q1 conducting), and the voltage at the collector of A3Q1 will drop to a very low value. Since capacitor A3C10 is now positively charged, diode A3CR6 will be reverse biased and will not conduct. This will allow capacitor A3C10 to discharge through A3R40, a 220,000 ohm resistor. After approximately 2 milliseconds A3C10 will have discharged sufficiently to cut off A3Q14, resetting the retrigger delay multivibrator and dropping the collector of transistor A3Q12 to a low voltage value. At this time the coupling diode A3CR3 will be reverse biased, isolating the operational integrator from the retrigger delay multivibrator. The operational integrator will again receive a negative input current from resistors R30 and R31, initiating the next sweep.

During the sweep, when the base of A3Q14 is biased to cutoff, A3Q15 is also biased to cutoff, so that the +100V supply is connected to the SWEEP light through A3R48. When retrace is initiated by application of a positive voltage to the base of A3Q14, A3Q15 is biased for heavy conduction and the resulting current flow through R47 drops the voltage applied to the SWEEP light, thereby extinguishing it. The light remains off until the base of A3Q14 is biased to cutoff at the start of the next sweep.

If the SWEEP TRIGGER switch S10 is in the EXTERNAL, LINE, or MANUAL positions, diode A3CR1 is connected to the junction of A3R22 and A3R32. This places ≈+ 3V on the cathode of A3CR1, to reverse-bias it. In these modes, the reset pulse for the retrigger multivibrator is derived from the Schmitt trigger circuit, which consists of A3Q11 and A3Q10 driven from A3Q9. If the FREQUENCY mode selector switch S14 is in either sweep position, the base of A3Q16 will be + biased through A3R49 to saturate and provide a ground connection for the A3Q8/A3Q9 emitters. In the MANUAL position of the SWEEP TRIGGER switch, pressing the MANUAL TRIGGER button S9 applies +15V through resistor A3R19 to the base of A3Q9. This causes A3Q9 to conduct heavily and its collector voltage will fall to a few tenths of a volt. This voltage, coupled to the base of A3Q10, causes the Schmitt circuit to reverse stages, with A3Q10 conducting and A3Q11 cut off. The resultant negative step function at the collector of A3Q11 will be differentiated by A3C8/A3R32, and the negative pulse is applied through A3CR1 to reset the retrigger multivibrator. Subsequent operation of the circuit is the same as in the FREE RUN mode.

If the SWEEP TRIGGER selector switch is placed in the LINE position, the input to the trigger generator circuit A3Q9 is derived from the power transformer T1. The biasing of A3Q9 is such that a negative trigger pulse will be generated each time the input waveform crosses zero in a positive direction. Since it is not desired to get a trigger pulse until the retrace is complete, it is necessary to de-activate the trigger circuit until that time. This is done by means of the trigger hold-off amplifier A3Q8. The base of this amplifier is connected through A3R17 to the 40 V sweep. Thus, as long as the sweep is positive, transistor A3Q8 will conduct. This conduction holds the collector voltage of A3Q9 at very close to zero volts. It then becomes impossible for trigger voltages to appear at the collector of A3Q9 and thus at the base of A3Q10. As soon as the 40 V sweep goes to zero during the retrace, A3Q8 will stop conducting. Its collector will go positive, resetting the Schmitt trigger by cutting off A3Q10 and turning on A3Q11. (The resultant positive output spike is isolated from A3Q2 by A3CR1.) The trigger generator circuit will then be ready to accept a trigger.

Once the next sweep ramp is triggered, further negative pulses from the Schmitt trigger will not affect the retrigger multivibrator. By the time the sweep output again resets the retrigger multivibrator, the Schmitt trigger is inhibited by the positive sweep voltage as described above until retrace is completed.

A ground connection is applied to terminal W of A3 when the FREQUENCY Mode Selector switch S14 is in the SINGLE frequency or OFF modes. This keeps transistor A3Q16 cut off, so that A3Q8 and A3Q9 cannot conduct. Thus, no sweeps can be triggered during these modes, and the ramp generator therefore rests at zero volts. In the EXTERNAL trigger position, positive trigger pulses can be introduced to A3Q9 by way of a front panel BNC connector.

When the retrigger multivibrator is switched to the A3Q2 conducting state to start the retrace period, the negative step-function collector output of A3Q2 is applied through A3CR8 to the panel RETRACE and FREQUENCY Mode Selector switches. In the RETRACE OFF condition this ground-level signal is connected to the modulator circuitry on PC Board A5, to turn the rf output off during retrace and until the next sweep is triggered. In the FREQUENCY OFF position of S14, it drives the modulator to keep the rf output off. This near-zero level is also applied by way of voltage divider A3R9 and A3R10 to the base of A3Q3. A3Q3 will then be cut off during retrace only, so that its collector will be at approximately zero volts during the forward sweep and approximately +50 volts during the retrace and until the triggering of the subsequent sweep. This 50 V blanking pulse has approximately a 10 K source impedance, and is connected to the BLANKING OUTPUT connector on the front panel.

4.12 SWEEP OUTPUT CIRCUIT. (See Figure 4-14.)

The sweep output circuit shown in Figure 4-14 is used to generate the sweep drive signal for the panel frequency controls. The output of these controls drives the summing junction in the cathode supply operational amplifier, and provides a sweep-level output to the marker circuits for use in determining coincidence between the sweep and the preset marker frequencies. The sweep output circuit also provides the 0 to +15 V monitoring signal for the front panel SWEEP OUTPUT connector. The active circuitry is contained on part of Helix Overcurrent PC Board A7.

The input signal to the sweep output circuit is the 40 V sweep ramp output from the sweep generator circuit in A3. It is fed through a voltage divider consisting of A7R10, A7R9, A7CR1 and A7R16 to the base of A7Q5. A7Q5 is an emitter follower which provides a high-impedance input to avoid loading the ramp generator, and furnishes sufficient output drive for both the marker and sweep control circuits. The "Sweep Amplitude" chassis adjust control A7R9 adjusts the gain of A7Q5 to provide an output sweep level of exactly +15 V maximum. The 0 to +15 V sweep output, at pin 23 of A7, is distributed to the front panel switching controls.

When FREQUENCY Mode Selector switch S14 is in the $F_1 \rightarrow F_2$ swept mode position, S14E-4 connects the 0 to +15 V sweep to drive the F_2 control potentiometer R38. The wiper of R38 then taps off a reduced portion of the sweep sawtooth voltage corresponding to the setting of F_2 on the dial. This voltage is connected to the "sweep voltage input" terminal A1-U of the cathode supply. After impedance conversion in A1, it is coupled to the summing junction to provide swept drive from the starting frequency (set by the separate F_1 dc level input) to the F_2 frequency. The wiper position on the F_2 potentiometer R38 is such that it taps off sufficient voltage to sweep up to frequency F_2 from the low-frequency end of the band without considering the additional input to the cathode supply summing junction from the F_1 potentiometer (which will be zero only when F_1 is set at the low-frequency end of the band). Thus, a provision must be made to reduce the F_2 output voltage tapped from R38 when F_1 is set above the low end of the band; otherwise the top frequency would be $F_1 + F_2$. The necessary correction is to adjust the F_2 output from R38 to equal a voltage corresponding to the frequency increment ($F_2 - F_1$) at sweep sawtooth maximum. This is done by a mechanical differential gearing arrangement in the dial drive mechanism. All the marker control knobs incorporate a 1:2 overdrive gearing arrangement to provide maximum potentiometer sensitivity with a minimum of dial rotation. The gearing of the F_1 and F_2 controls is arranged so that the F_1 control, in addition to operating the wiper of F_1 potentiometer R41, also rotates the body of F_2 potentiometer R38 around its wiper to reduce the R38 output voltage by an amount equal to the R41 output. This brings the R38 output to the necessary ($F_2 - F_1$) maximum value. The wiring connections to R38 are made by means of a coiled cord to permit this rotation without sacrificing wiring reliability.

When FREQUENCY Mode Selector switch S14 is in the $F_0 \pm \Delta F$ position, S14E-3 connects the 0 to +15 V output from A7-23 to an attenuating and dc offset network consisting of R66, A7R7 and A7R6. This network offsets the signal output midpoint level applied to terminal 21 to exactly zero volts, and reduces the sweep amplitude by 10:1, so that the sweep sawtooth applied to A7-21 runs from -0.75 to +0.75 V. A portion of this zero-centered, reduced-amplitude sweep signal is tapped by the ΔF control potentiometer R42 and applied to the "sweep voltage input" terminal A1-U of the cathode supply. In this mode, the output of F_0 control potentiometer R44 is connected to the "dc level input" terminal A1-R of the cathode supply. The zero-centered sweep thus adds to the fixed F_0 level at the cathode supply summing junction, to sweep the output frequency symmetrically around F_0 by an amount corresponding to the ΔF setting.

When the FREQUENCY Mode Selector switch S14 is in the $F_1 \rightarrow F_2$ or $F_0 \pm \Delta F$ positions, the 0 to +15 V sweep output from A7Q5 is coupled through pin 22 of A7 to the base of A7Q4, the emitter follower driver for the SWEEP OUTPUT connector J11. The 0 to +15 V output from A7Q4 is fed through 10 K resistor A7R5, which serves as a source impedance for the external using circuit. The CALIB button S7 connects J11 through another 10 K resistor, R32, which is tied to the +15 V supply to

furnish a +15 V calibration output.

4.13 MARKER GENERATOR CIRCUIT. (See Figure 4-15.)

The purpose of the marker circuit is to provide wavemeter-like pips to indicate preset frequencies selected with the F_0, M_1, or M_2 Control Knobs. One marker pip is electronically generated when the rf output crosses each selected marker frequency. The markers are generated by determining the time of coincidence between the absolute level of the 0 to +15 V sweep output signal and the preset marker generator signal level between 0 and -15 V, which corresponds to the position of each marker frequency in the swept spectrum. At each instant of coincidence, a modulation pulse is applied to the leveling circuit to momentarily reduce the output level. Each instant of coincidence is determined by a separate summing junction and operational amplifier for each of the three markers contained in Markers PC Board A4.

A description of the control signals which drive the cathode supply summing junction to control the frequency of oscillation of the oscillator tube is given in Paragraph 4.5. These same control signals are also used to drive the marker generator summing junctions, as a linear representation of instantaneous output frequency. These two control signal voltages are the "dc level" (start frequency) and "sweep" control signals which are tapped from the appropriate panel potentiometers by the front panel FREQUENCY Mode and SINGLE Frequency Selector switches S14 and S15. They are applied to terminals U and R of A1, as shown in Figures 4-7 and 4-17, and are impedance-converted on the A1 board. In addition to driving the cathode supply operational amplifier summing junction through 15 K, the control signal outputs from the two impedance converters are supplied to terminals S and P of A1. These outputs are used to drive the marker circuit summing junctions as shown in Figure 4-15.

The impedance converter outputs used in the marker circuits are connected to each summing junction through 100 K resistors. These resistors prevent any loading effect on the cathode supply impedance converters. To balance the source impedance of all inputs to the marker circuit summing junctions, the output signal from each marker control is also applied through a 100 K resistor. The signals applied to the cathode supply summing junction are then isolated from all inputs to any marker circuit summing junction by an effective impedance of about 200 K. This provides effective isolation, when compared with the low-impedance drive of the desired signals supplied from the impedance converters.

Only one marker circuit summing junction is shown in Figure 4-15. The signals from A1-P and A1-S are applied to all three circuits. The other two circuits are identical to the M1 circuit shown, except for the top input signal from the marker control potentiometer. (Different reference designators are also assigned to the other circuits, since they are all contained on PC Board A4; the complete A4 schematic is provided at the back of the manual.) The M_1 channel will be described as an example. The voltage input from MARKER control M_1, tapped from linear potentiometer R48, varies from 0 to -15 V linearly, depending upon the setting of M_1 on the frequency scale. The sum of the control voltages applied to A1-P and A1-S varies with instantaneous frequency through the same linear range, but with opposite polarity (0 to +15 V). Thus, the M_1 marker circuit summing junction will pass through a 0-volt null when the output frequency crosses the selected marker frequency. The marker generator, consisting of A4Q7 through A4Q12, indicates this momentary null condition by producing an output voltage change.

In the M_1 channel the marker generator consists of three cascaded amplifier stages (A4Q7, A4Q8 and A4Q9), a double-ended phase inverter stage (A4Q10 and A4Q11, a positive pulse-summing full-wave rectifier (A4CR7 and A4CR8), and an output emitter follower (A4Q12). Due to the very high gain of the amplifier, a very small variation in the input voltage above or below zero volts will drive its output from positive to negative saturation. Diode A4CR6 biases transistor A4Q7 to cut off when the summing junction potential is below 0 (it rests at about -0.5 V at the start of each sweep due to the negative signal from the marker potentiometer). The two following stages will conduct heavily when A4Q7 is cut off, thereby raising the base of A4Q10 to +15 V and keeping it cut off so that A4Q11 conducts heavily. Thus, if the frequency is swept very slowly up to the marker position, the voltage at the collector of A4Q10 will start out negative and suddenly jump to a positive value as A4Q7 starts to conduct and thereby turns on A4Q10. The voltage at the collector of A4Q11 will start out positive and suddenly jump to a negative value, as the turn-on of A4Q10 drops the emitter of A4Q11 below the cutoff point for its fixed base bias.

The two step functions of opposite polarity supplied from the collectors of phase inverters A4Q10 and A4Q11 are applied to rectifier diodes A4CR7 and A4CR8. These diodes are connected to the base of A4Q12. The input waveform at A4Q12 is therefore a narrow, negative triangular pulse with about half the amplitude of the step function pulses. The leading edge of the triangular pulse is formed by the fall of the negative-going step function, and the trailing edge is formed by the rise of the positive-going step function. The tip of the output triangular waveform of A4Q12 thus represents zero volts at the summing junction. The collector of A4Q11 is connected through a resistive network back to the input of the amplifier for negative feedback stabilization.

The output of A4Q12, the triangular marker pulse, is combined with the markers from the other two marker channels and applied through resistor A4R74 to the base of A4Q19, another emitter follower. The output of A4Q19 feeds the marker pulses either to the front panel MARKER OUTPUT connector, (only in the switched EXT position of the MARKER AMPLITUDE control) or to the modulator PC Board A5, where the pulses are used to alter the voltage applied to the leveler amplifier to produce a pip in the power output. The marker output line is normally at ground level, and the pulse amplitude ranges up to -2 V. From the leveler-amplifier the markers are applied to the PIN-diode leveler or to the tube grid via the transfer oscillator and elevated supply. They modulate the rf output with absorptive marker pips, in leveled operation. For unleveled operation, the video pips available at the OUTPUT MARKER connector can be combined at the oscilloscope or recorder input with the detector output from the rf circuit, to provide markers in the display.

Marker amplitude is controlled by bleeding off a variable portion of the marker pulse drive current from the base of A4Q19 by means of MARKER AMPLITUDE potentiometer R37, which adjusts the return level of A4R73. With R37 at the OFF limit of rotation, A4R73 is returned to +15 V, and all drive current is shunted away from A4Q19. As R37 is turned CW, lowering the return voltage of A4R73, it becomes a less attractive shunt path for the marker pulse drive current, so that A4Q19 is driven to provide a variable marker pulse amplitude up to a maximum of -2 V. Diode A4CR13 prevents the base voltage of A4Q19 from being shifted above +0.6 V by the adjustment of R37.

During retrace in swept modes, the positive blanking voltage is supplied through A4R77 to inhibit the markers by shunting away all drive current. This blanking signal is removed from A4-T in the manual sweep mode by S14-O, to allow markers during manual sweep. (The M_1 and M_2 MARKERS potentiometers are disconnected from the marker generator circuit in all single-frequency modes except F_2, to inhibit markers except in the mode where manual sweep may be used.) "M_1 Cal" resistor A4R32 and summing resistor A4R31 inject a fixed offset current

into the summing junction to permit marker dial calibration coinciding with the calibration of the frequency control dials. This compensates for tolerance variations in the components. Diode A4CR6 supplies a bias of -0.6 V to the emitter of A4Q7, so that its base, which will be at +0.6 V with respect to its emitter due to V_{BE}, will be biased at zero volts. If this were not done, the amplifier would become active, that is, unsaturated, when the summing junction voltage is +0.6 V rather than zero volts, placing a fixed offset error in the system. Another function of A4CR6 is to provide temperature compensation at the input of the marker circuit. Diode A4CR5 clamps the summing junction to ground to prevent unnecessary rises above 0 V after the trigger pulse has been generated.

4.14 MODULATOR. (See Figure 4-16.)

The amplitude modulation circuitry combines several modulating signals, sums them,and applies them to the oscillator plug-in unit in the form of biasing voltage variations. Connections and circuit boards contained within the plug-in units provide final determination of the applied voltage levels and connection configuration for the microwave tube. Accordingly, modulation signals applied to BWO plug-in units are converted to grid-to-cathode voltage variations, and modulation signals applied to VTM plug-in units are converted to injector-to-cathode voltage variations.

The amplitude modulator circuitry is contained on Modulator PC Board A5. The signals used in the modulator for driving the plug-in include:

a. The internally-generated square wave (produced by stages A5Q1 through A5Q4).

b. The blanking impulse used to turn off the rf power during sweep retrace and when the FREQUENCY Mode Selector is OFF (applied to A5Q8 from the sweep circuit).

c. The marker pulses (applied to A5Q7 from the marker circuit).

d. External amplitude modulating signals (coupled through the plug-in unit to A5Q3).

e. The rf turn-on and turn-off voltages received from the MODULATION Mode Selector switch S12, the RETRACE Selector switch S12, the RETRACE Selector switch S13, and the FREQUENCY Mode Selector switch S14 (applied through A5-X and A5-T).

The modulator output, at A5Q5, is coupled to the plug-in unit through the transfer oscillator, which raises the signal level to the elevated potential at which the tube operates. The transfer oscillator also combines another modulating signal - the leveler-amplifier output - with the modulator output signal to obtain the over-all power amplitude control signal for the microwave tube, in grid-leveled plug-in units.

In the internal square wave generator circuit, unijunction transistor A5Q1 serves as the oscillator, and operates at twice the square-wave frequency. The output pulses from A5Q1 are differentiated by A5C2 and A5R6, and applied to A5Q2. There, the positive pulses are amplified, reversed in polarity, and applied to a bistable multivibrator circuit containing A5Q3 and A5Q4. This circuit switches states and produces a 1 V output voltage swing that constitutes half a square wave cycle in response to each input pulse, thereby dividing the 2 kc pulse frequency by two, producing a 1 kc, 1 V peak-to-peak square wave. The output of this square wave multivibrator is obtained across A5R11 and applied to A5Q5 and A5Q6.

The signal from the collector of A5Q5 drives the transfer oscillator for modulation coupling to the plug-in. The signal from A5Q6 supplies the reference voltage for the leveler circuitry in the plug-in, so that it will not correct for desired modulation. The open-circuit output voltage from A5Q5 will be either 0 or +15 V corresponding to the +1 V and 0 V half cycles, respectively, of the driving square wave. Similarly, the voltage at the collector of A5Q6 will be either 0 or +7.5 V. (The collector of A5Q5 is returned to +15 V, while the collector of A5Q6 is returned to a voltage divider between +15 V and -15 V.) Due to the same voltage divider, the corresponding open-circuit output voltage from A5Q6 at terminal R, which feeds the reference voltage to the leveler, will be either -5 V or 0.

The voltage output at terminal R will be modified by the marker injection signal amplified by A5Q7, the collector of which is connected to the junction of A5R26 and A5R27. The negative marker pulses applied at A5-P cause A5Q7 to conduct, raising the voltage at this junction from -10 V to a less-negative voltage ranging up to -4 V, depending upon the amplitude of the marker supplied from the marker circuit. Thus, the -5 V or 0 V output at terminal R will be raised to -2 or +1.75 V, respectively, during application of a maximum-amplitude marker. Since -5 V is required at A5-R to obtain the full-on (CW or swept) rf output level, the resultant -2 V signal will produce an amplitude reduction "pip" in the output level which serves as a marker. The nominal 0 to +15 V square wave level applied to the transfer oscillator through A5F is reduced to almost +11 V peak by output loading. This signal operates so as not to interfere with the rf output level during the 0 V portions of the output signal, and to reduce the rf output level when the square wave goes positive. Note that there is a phase reversal between the output of A5Q3 and the modulation signal applied to A5-F and A5-R.

Except for the markers, all other on-off control signals supplied to the modulator are applied at the base of A5Q3, the output stage of the square wave multivibrator. For operation without amplitude modulation, the MODULATION Mode Selector switch S12 applies +15 V to the base of A5Q3, to hold it in conduction. This is the condition corresponding to the +1 V portion of the A5Q3 output wave, as required to supply a 0 V signal to the modulator to allow the rf to remain on.

In the EXTERNAL MOD position of the Mode Selector switch, the positive A5Q3 bias is overcome by applying -15 V to terminal X and through A5CR4 and A5R22 to the base of A5Q3. A5R21 and A5R22 then constitute a voltage divider which places a negative bias on the base of A5Q3. This will hold A5Q3 cut off, and its output level will be zero, causing the rf to be turned off. In this condition, no rf output is supplied until positive voltage is applied to the EXT AM INPUT connector on the plug-in front panel. This voltage is connected to terminal A5-V, and through A5R20 and A5CR5 to the base of A5Q3. A sufficient positive input voltage (approximately +10 V) at the base of A5Q3 will buck out the negative bias and cause the multivibrator to change states, turning on the microwave oscillator tube. In the SQUARE WAVE position of Mode Selector switch S12, the +15 V supply is connected to the collector dropping resistors of A5Q1 and A5Q2, allowing them to operate to produce the internal square wave. This +15 V is removed in other modulation modes when the internal square wave is not required.

During swept operation, the retrace blanking pulse supplied at terminal W passes through the network A5R28, A5C6, and A5R29, and then is applied to A5Q8, an emitter follower. The signal as applied to A5-W is about 0 V during retrace and about +15 V during each sweep. The connection of A5R29 to

-50 V adjusts the blanking pulse level applied to the base of A5Q8 to -6 V during retrace and +2 V during the sweep. The result is that A5Q8 conducts heavily during the sweep and lightly during retrace, providing an emitter output level of +1.5 V and -7 V, respectively. The signal from the emitter of A5Q8 is coupled out through A5CR3 and A5CR4. The -7 V signal coupled through A5CR3 during retrace turns off amplifier A5Q2. This prevents pulses from the unijunction transistor from driving the multivibrator. The -7 V signal coupled through A5CR4 is applied to the base of multivibrator output transistor A5Q3, holding that stage cut off during retrace, the condition required to produce an "rf off" output signal from the modulator. If the RETRACE selector switch S13 is placed in the ON position, to keep the rf on during the retrace, terminal A5-X is grounded when the FREQUENCY Mode Selector switch S14 is in one of the swept mode positions. This prevents the negative blanking impulse from being applied to keying diodes A5CR3 and A5CR4 so that the rf output (with modulation) remains on during the retrace interval.

In the SINGLE frequency mode, except when external modulation is used, terminal X is grounded to disable the retrace blanking circuit and allow the rf output to be on continuously unless internal square-wave modulation is used. In the OFF frequency mode, terminal X is left open-circuited, so that the retrace blanking signal, which is provided continuously from the disabled sweep generator in this mode, will drive A5Q8 to hold the modulator in the "rf off" condition.

4.15 TRANSFER OSCILLATOR. (See Figure 4-16.)

The transfer oscillator is used as a coupling system to permit both the modulation signal and the dc voltage from the leveler-amplifier (when used) to be transferred to the elevated grid potential of a BWO or the elevated injector potential of a VTM. Accordingly, the input and output of the transfer oscillator must be isolated for at least 2500 V dc, and the circuit is contained on a separate board, A9. The transfer oscillator circuit receives its modulation signal from A5-F on the modulator PC board. This signal will be at 0 V when rf output is desired from the microwave tube, and +11 V when the rf output is to be turned off. This signal is combined with the leveler output in such a way that signals which tend to reduce the rf power level take precedence. Thus, modulated output can be obtained within a leveled envelope.

The circuit consists of a 45-megacycle oscillator (A9Q1), a 45-megacycle oscillator output amplifier and modulator (A9Q2 and A9Q3), a balanced demodulator consisting of a transformer, rectifier, and filter, and the output driver transistor (A9Q4). The current through A9Q4 drives the modulation electrode voltage control transistor A12Q1 in the elevated supply PC board within the plug-in unit. Circuit component values associated with A12Q1 in the plug-in are selected as necessary to provide the proper control voltage for each microwave tube type and frequency range.

Transistor A9Q1 and the associated L-C circuit components form a shunt-fed Colpitts oscillator. A9C2 is the feedback capacitor. The oscillator output is coupled to amplifier A9Q2 through capacitor A9C6. This output has a constant level, but the 45-mc signal coupled to demodulator transformer A9T1 is varied in proportion to the amount of level-reduction required in the final rf output, through the action of the oscillator output amplifier and modulator, A9Q2 and A9Q3. The output from A9Q2 is developed across A9L4 and coupled to transformer A9T1 by A9C7 and A9C9. The 45-mc signal output level supplied by A9Q2 is dependent upon the conduction of modulator amplifier A9Q3, since this, in turn, determines the positive reference level to which A9L4 is returned. With heavy conduction of A9Q3 (due to a high positive signal applied to its base through A9-3 or A9-4), A9L4 will have a peak-to-peak drop of almost 15 V across it. With A9Q3 cut off, A9L4 will experience a negligible voltage drop, and therefore the 45 mc output signal from A9Q2 will be negligible.

Diodes A9CR1 and A9CR2 act as an adder which allows the more positive of the signals from the modulator (A9-3) or the leveler-amplifier (A9-4) to take control of A9Q3. The operation of both the modulator and leveler are such that a positive signal is supplied to the transfer oscillator when the rf output level is to be reduced. Thus, the 45-mc output signal level developed by A9Q2 is related to the desired amount of reduction in the rf output level.

The two 30-pf, 6000-volt coupling capacitors A9C7 and A9C9 supply the dc isolation between the transfer oscillator input and output circuits. The return line for the output circuit driven by A9T1 is the -100 V supply bus, which is -100 V from cathode potential. The primary of A9T1 is resonated by A9C8 for maximum signal transfer at 45 mc. The output of A9T1 is full-wave rectified by A9CR3 and A9CR4, to provide balanced demodulation without transferring 45-mc signals to the -100 V supply line. The resulting voltage is then filtered by the L-C stages and applied to A9Q4. This A9Q4 drive signal, which appears across A9R4, will be between 0 and +5 volt. It will produce a corresponding current through A9Q4 that varies between 0 and approximately 35 ma. This current is fed to the modulator electrode control transistor A12Q1 in the plug-in unit. In BWO plug-in units, this causes the grid voltage to vary between 0 and -61 volts (Varian tubes) or between 0 and -25 volts (Stewart tubes) for full-on to full-off control. In VTM plug-in units, it causes the injector voltage to vary from maximum positive (35 V-280 V) to zero for full-on to full-off control. Components in the A12Q1 output circuit in the plug-in are chosen to achieve the proper range of control voltage when less than the above voltage swing is required. The connection through C14 to the 0-line minimizes transients in the transfer oscillator output when power is switched off.

4.16 FREQUENCY CONTROL SWITCHING. (See Figure 4-17.)

Frequency control switching as it affects each individual circuit has been discussed in previous paragraphs. Figure 4-17 shows a complete functional schematic diagram of switches S14 and S15 with each position identified. It includes a capsule description of the purpose of each functional section, which can be used to obtain a more thorough knowledge of the circuit. For reference in trouble-shooting, the physical arrangement of each switch is also shown in Figure 4-17, with physical contact terminals numbered to agree with the functional schematic. These letter and number designations also agree with those used on the foldout schematics in the rear of this manual. See Paragraph 4.12 for a discussion of sweep frequency control switching.

4.17 MODULATION AND SWEEP CONTROL SWITCHING. (See Figure 4-18.)

For convenience in following the operation of S10, S11, and S12, functional schematics showing connections made in each switch position are given in Figure 4-18. For reference in trouble-shooting, the physical arrangement of each switch is also shown in Figure 4-18, with physical contact terminals numbered to agree with the functional schematic. These letter and number designations also agree with those used on the foldout schematics in the rear of this manual. The functions of each section of S10 and S11 are described in Paragraph 4.11. The functions of each section of S12 are described in Paragraph 4.14.

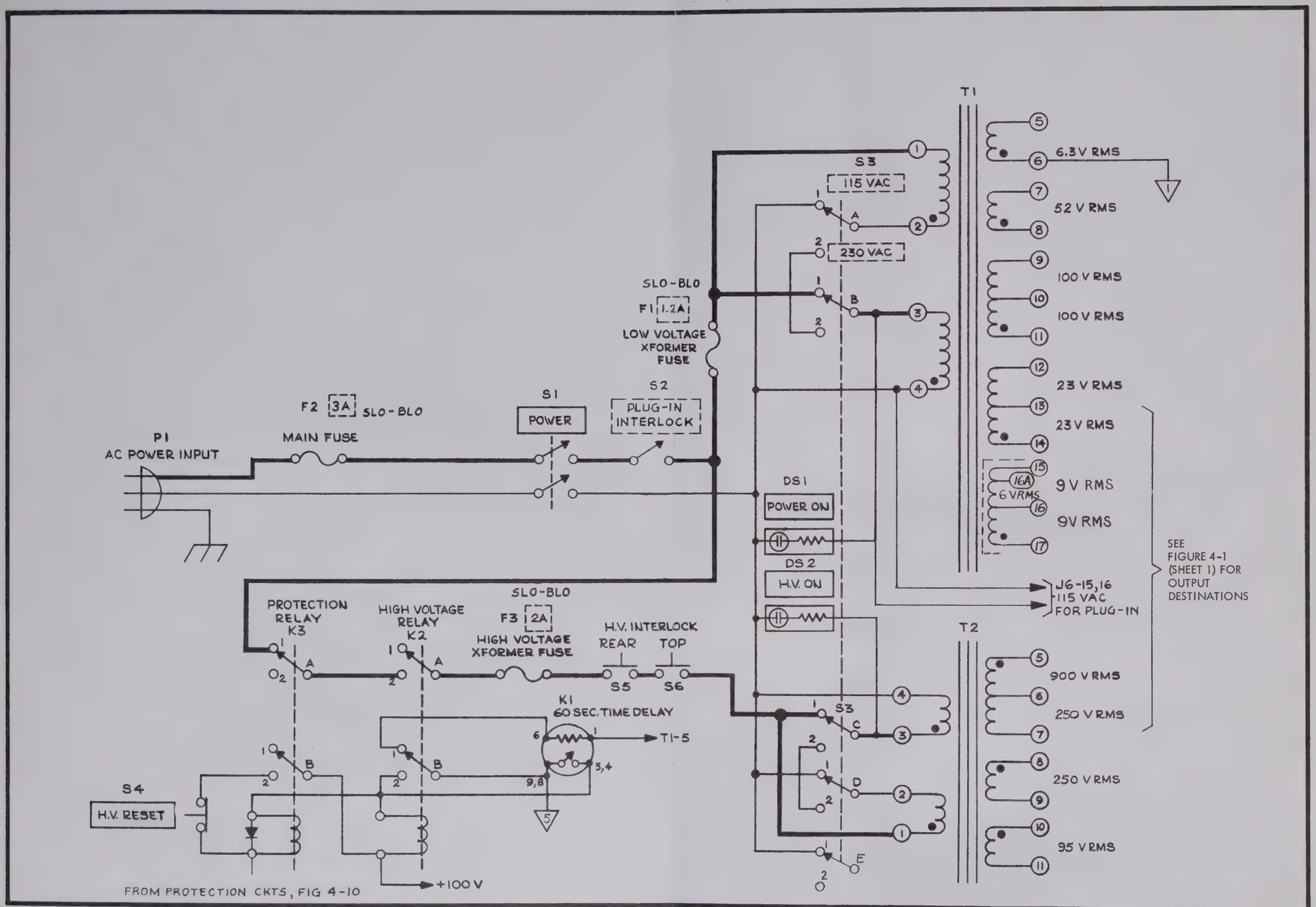
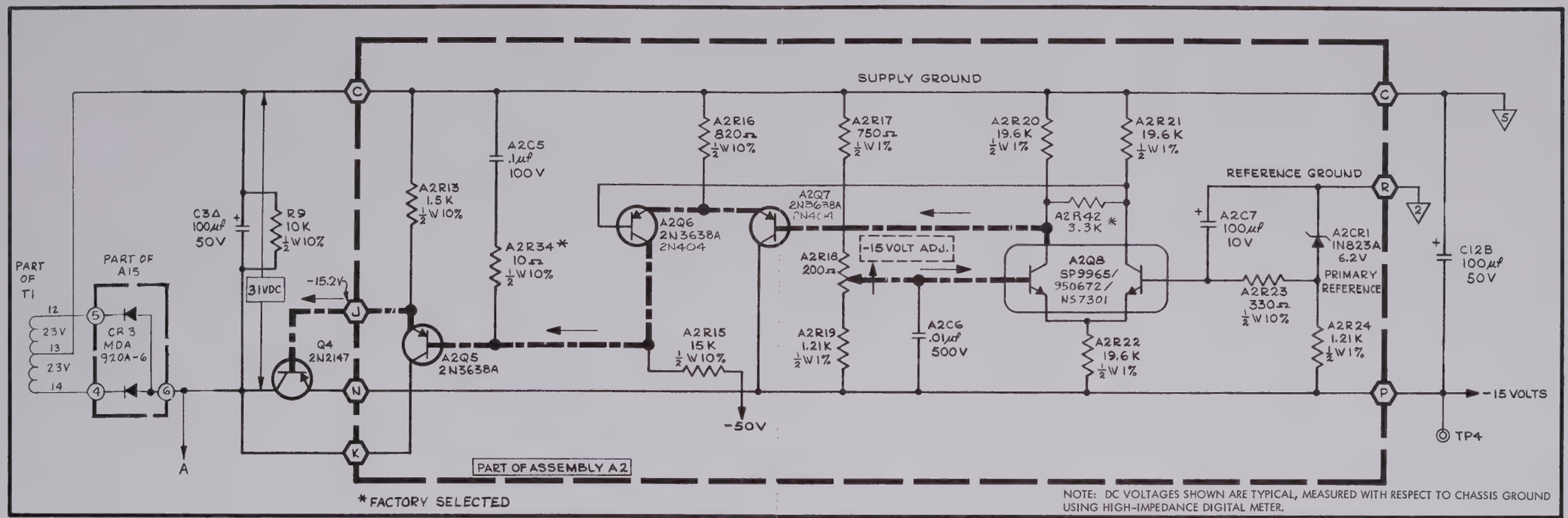
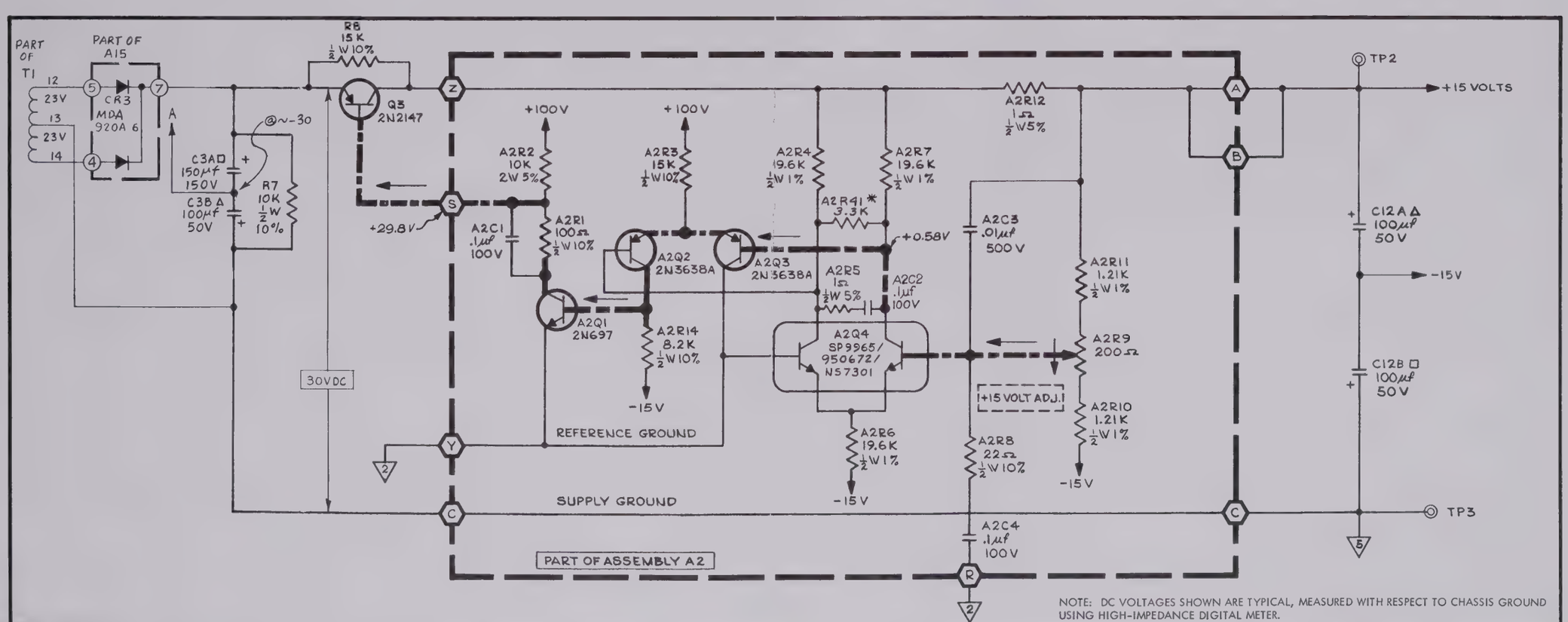


FIGURE 4-2
PRIMARY POWER DISTRIBUTION



IN S/N 1090 AND BELOW, CR4 THROUGH CR7 ON MAIN CHASSIS ARE USED INSTEAD OF A15CR3

FIGURE 4-3
-15 VOLT SUPPLY



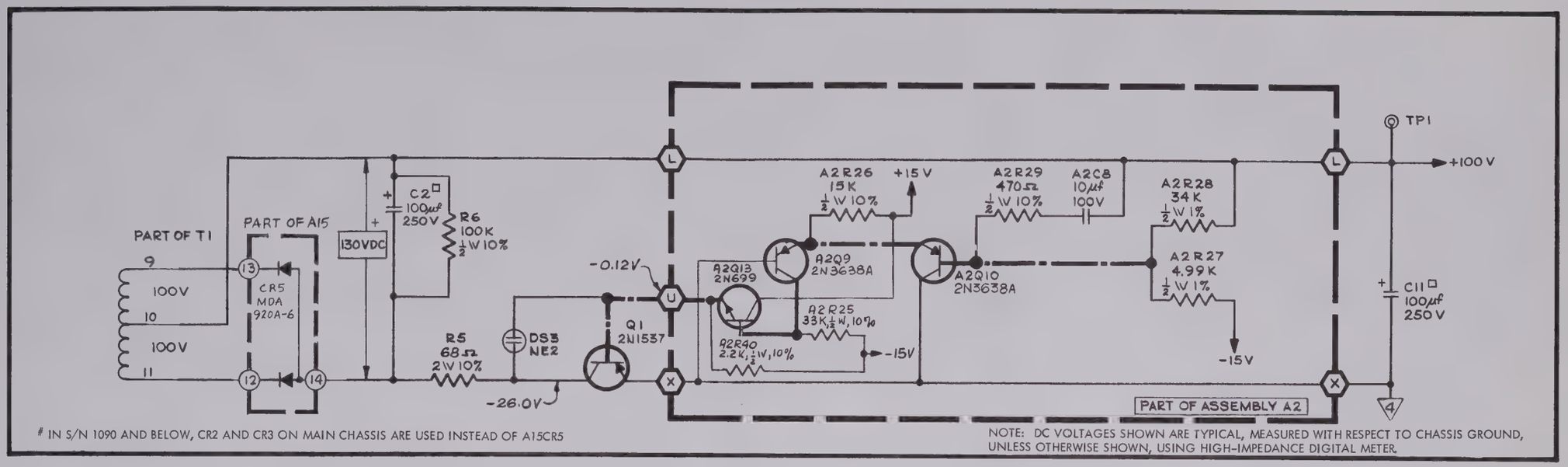


FIGURE 4-5
+100 VOLT SUPPLY

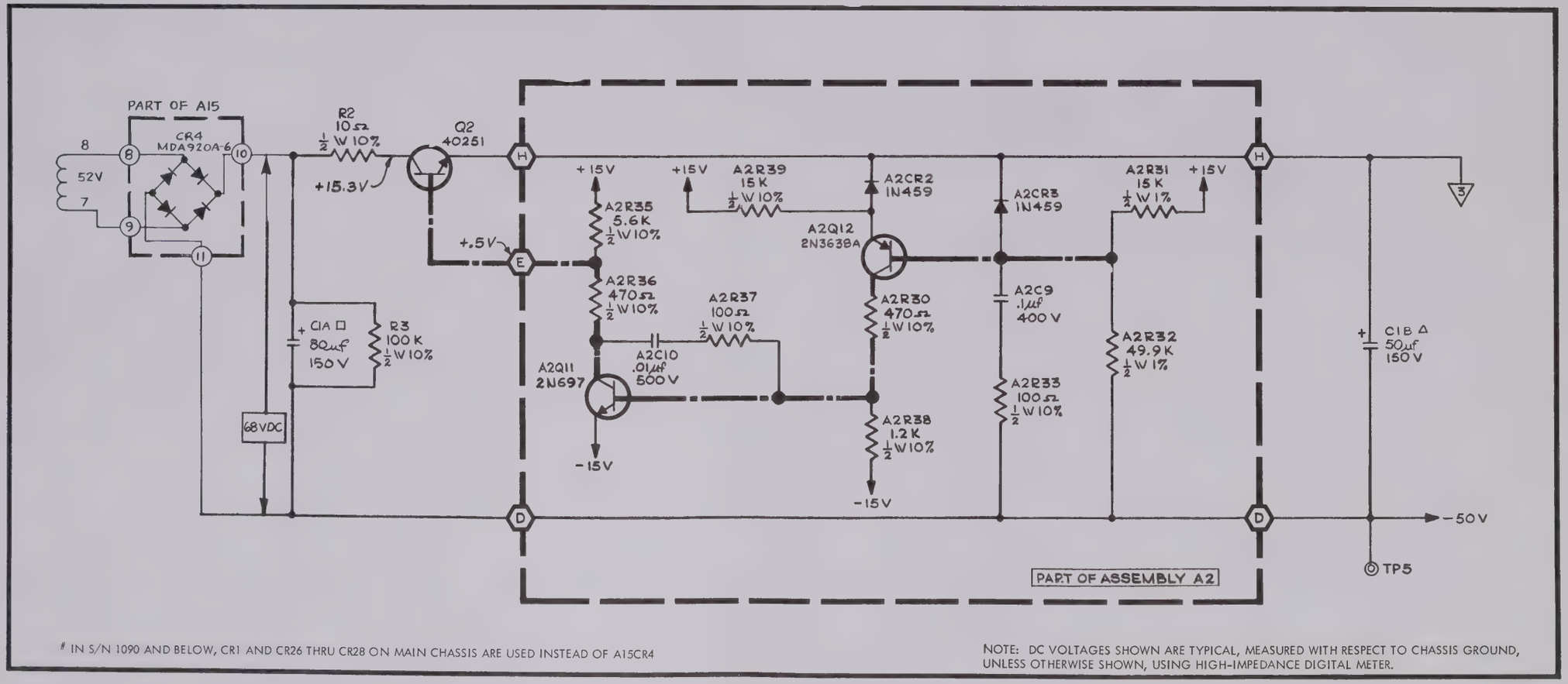


FIGURE 4-6

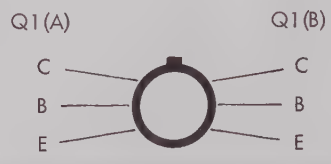
VOLTAGE MEASUREMENTS IN CATHODE SUPPLY MAIN FEEDBACK AMPLIFIER

If voltage measurements in the impedance converter input circuits feeding the Summing Junction indicate proper operation, use the following chart to short individual stages in the high gain amplifier A1Q1 - A1Q7 to isolate the defective stage.

NOTE:
If cathode supply output voltage rests at ≈+105 V (series regulator tubes cut off), start at the middle of chart by shorting the Q4 collector to emitter. If the following stages A1Q5, A1Q6, and A1Q7 are OK, this will turn the series regulator tubes full on to -3KV. This then indicates that the trouble is between A1Q1 and A1Q4. In that case, continue on down the chart until you cannot shift the cathode supply voltage. The trouble is then in the stage being tested or in the one on either side of it.

If shorting Q4 does not turn the cathode supply fully on, then proceed upward on the chart until you reach a stage where you can shift the output E. The trouble then will be in that stage or in the one on either side of it.

SHORTING CONNECTION	SUPPLY OUTPUT	POSSIBLE FAULT IF OUTPUT IS INCORRECT
Q7 B to E	+105 V	open Q7
Q7 C to E	-3 KV	shorted Q7
Q6 B to E	-3 KV	open Q6; shorted Q7; open Q5
C to E	+105V	shorted Q6; shorted Q5
Q5 B to E	-3 KV	open Q5; open Q6; shorted Q4
C to E	+105 V	shorted Q5; shorted Q6
Q4 B to E	+105 V	open Q4; shorted Q5; shorted Q3
C to E	-3 KV	shorted Q4; open Q5; open Q3
Q3 B to E	-3 KV	open Q3; shorted Q4; shorted Q2
C to E	+105 V	shorted Q3; open Q4; open Q2
Q2 B to E	+105 V	open Q2; shorted Q3; shorted Q1B
C to E	-3 KV	shorted Q2; open Q3; open Q1B
Q1B (signal output side) B to E	-3 KV	open Q1B; shorted Q2; shorted Q1A
C to E	+105 V	shorted Q1B; open Q2; open Q1A
Q1A (signal input side) B to E	+105 V	open Q1A; shorted Q1B
C to E	-3 KV	shorted Q1A; open Q1B



Q1(SP9965) as seen from top of board

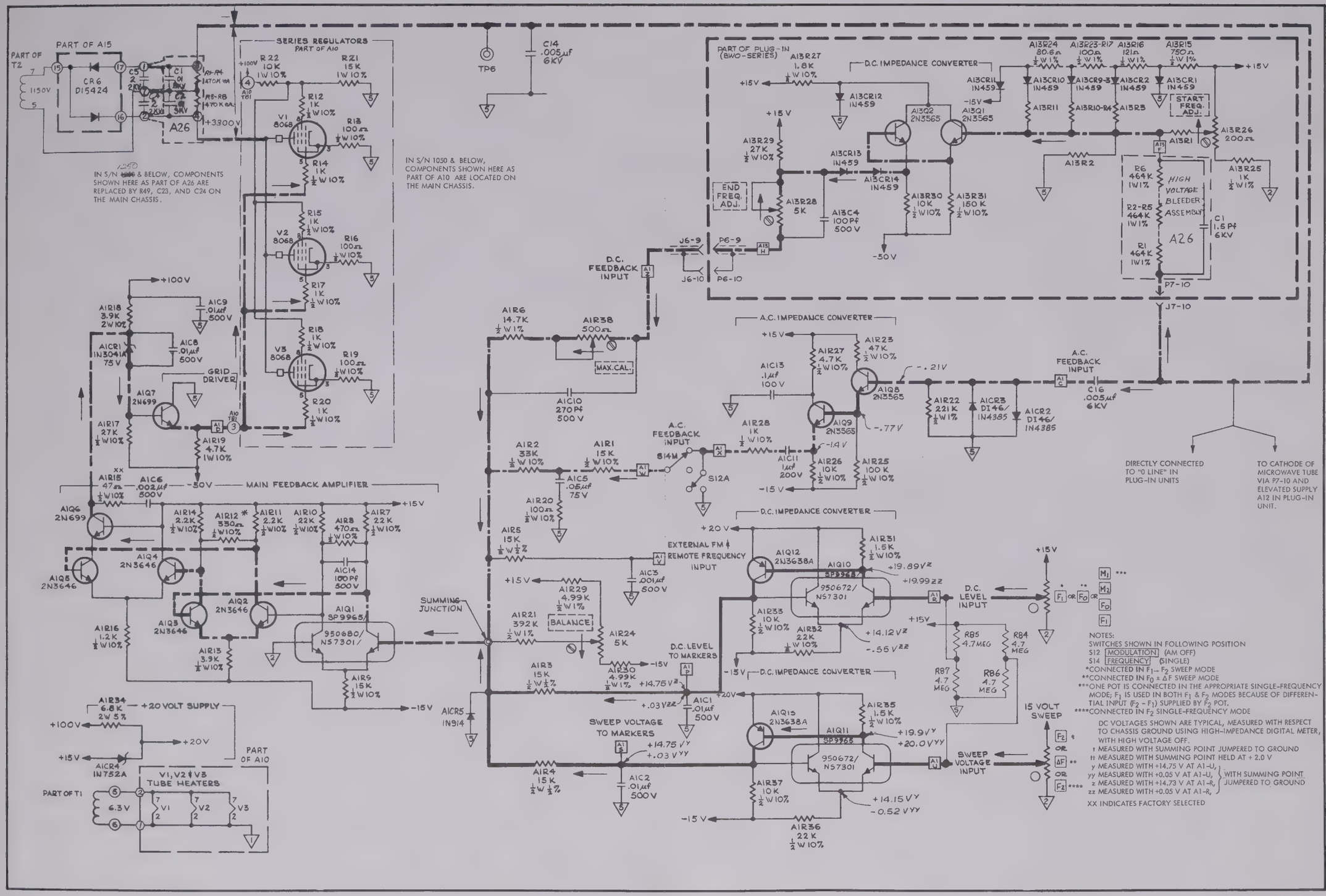


FIGURE 4-7
CATHODE SUPPLY

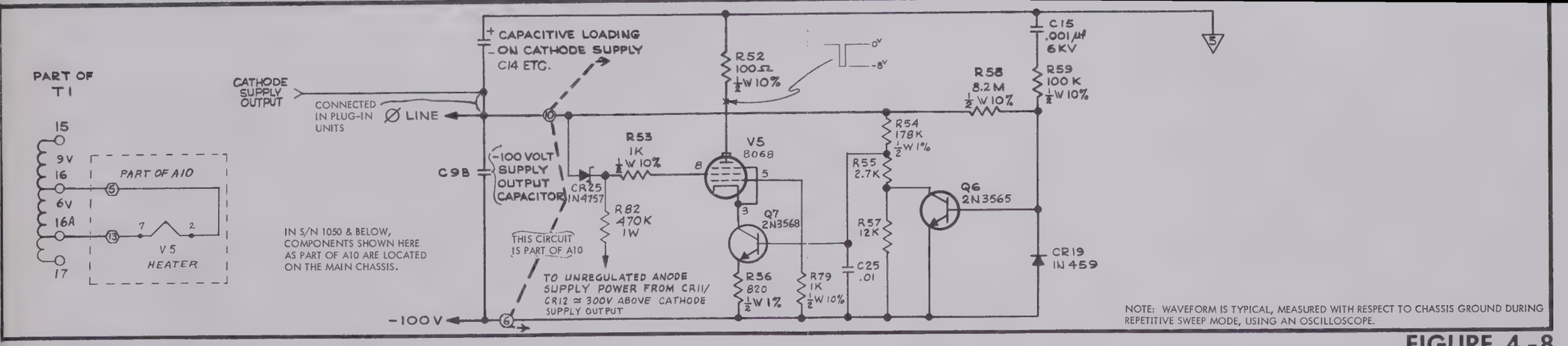
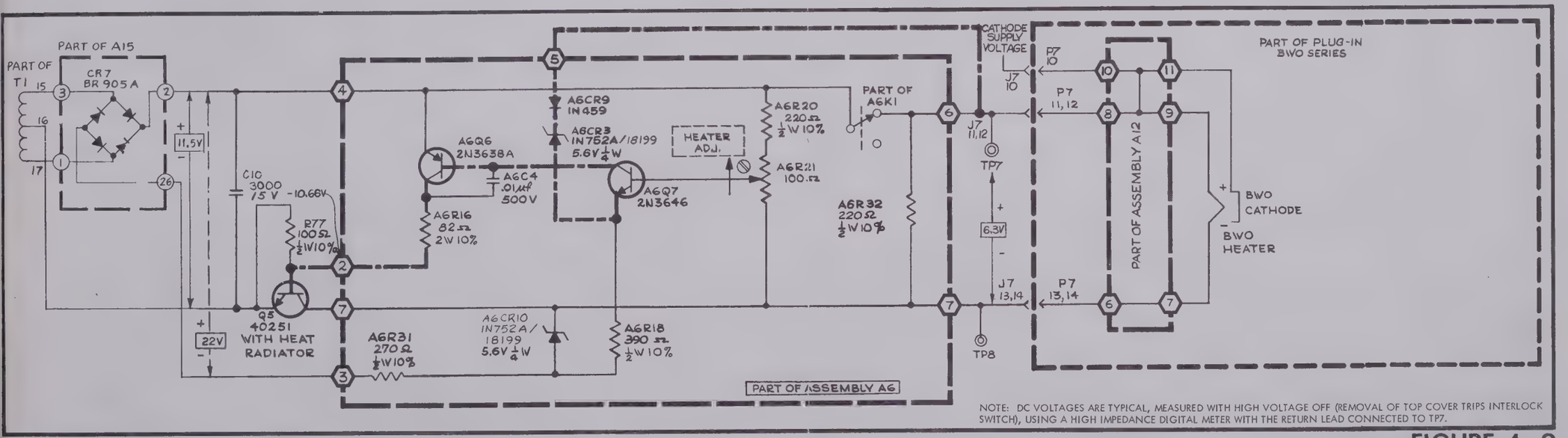


FIGURE 4-8
SWEEP RETRACE DISCHARGE CIRCUIT



* IN S/N 1090 AND BELOW, CR21 AND CR22 ON MAIN CHASSIS ARE USED INSTEAD OF A15CR9; AND CR17 AND CR18 ON MAIN CHASSIS ARE USED INSTEAD OF A15CR7 AND A15CR8

FIGURE 4-9
HEATER SUPPLY

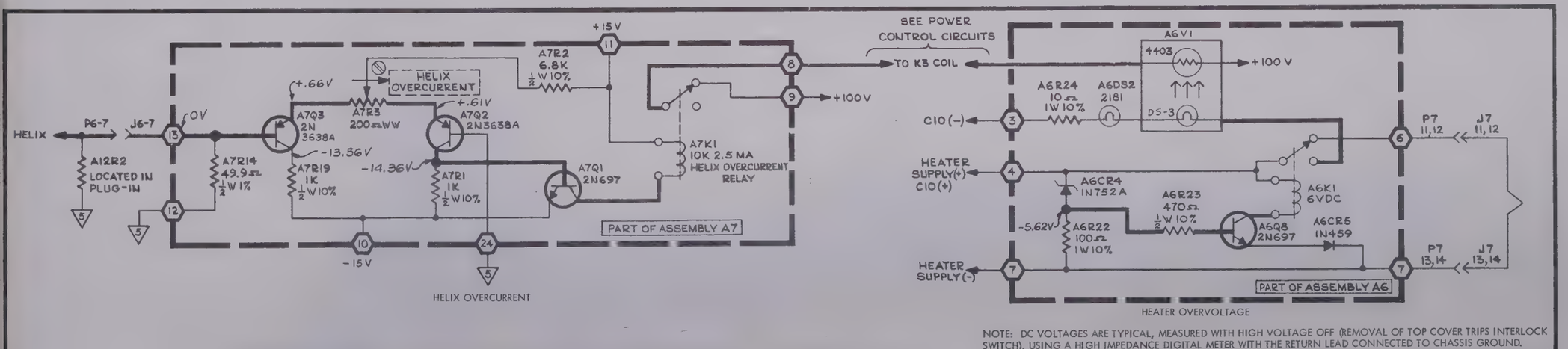
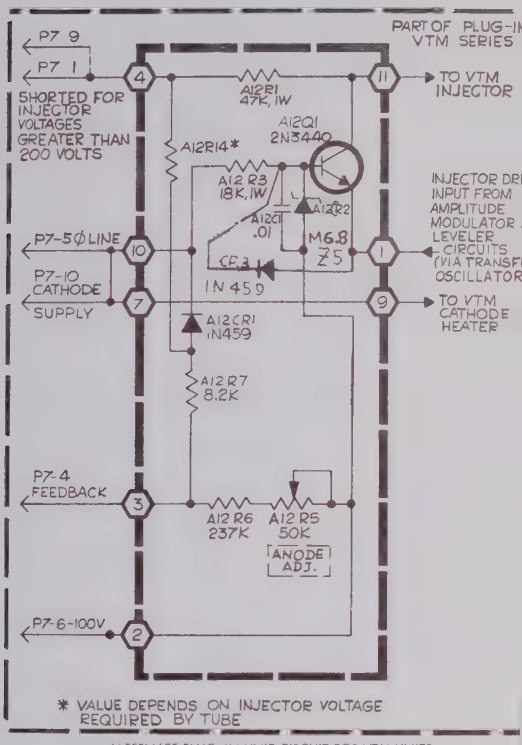
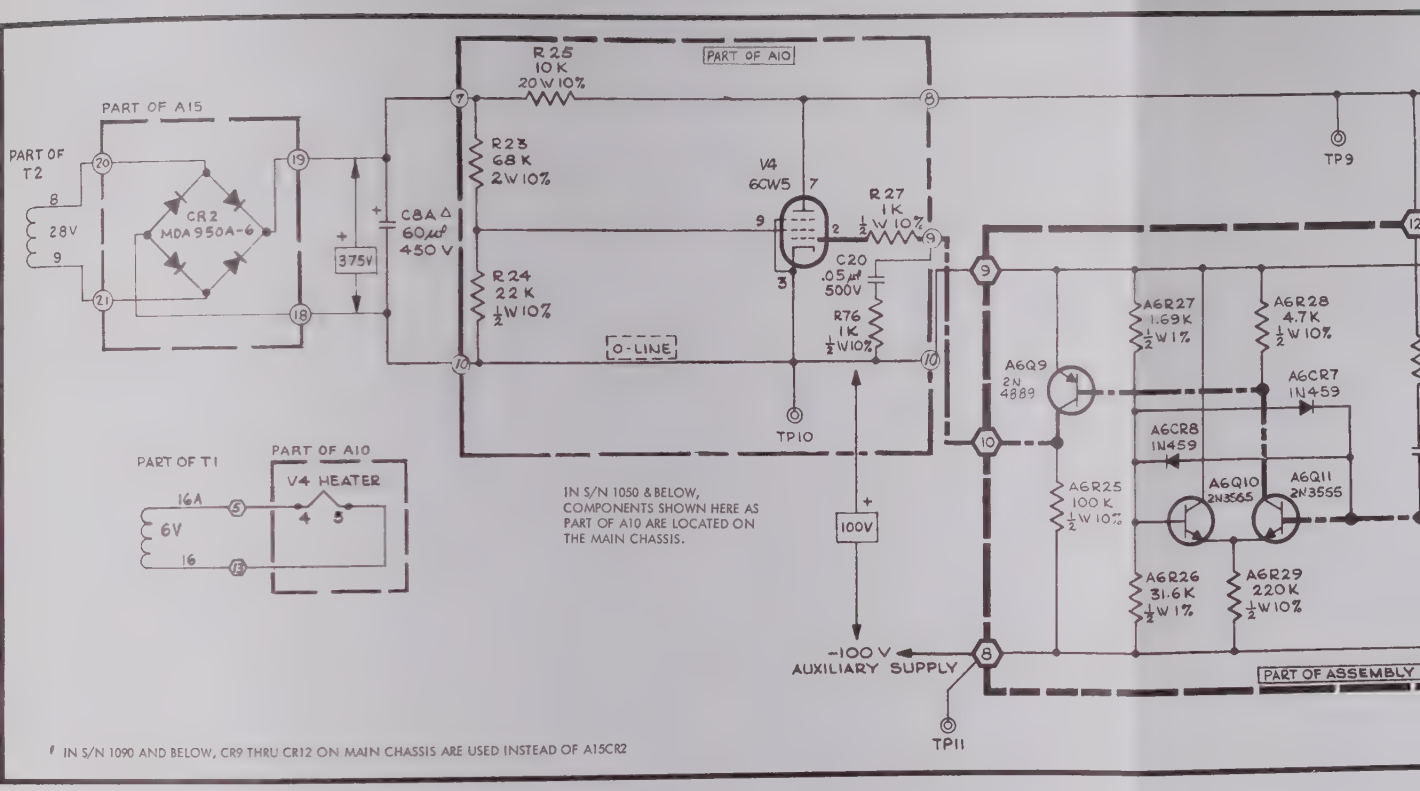


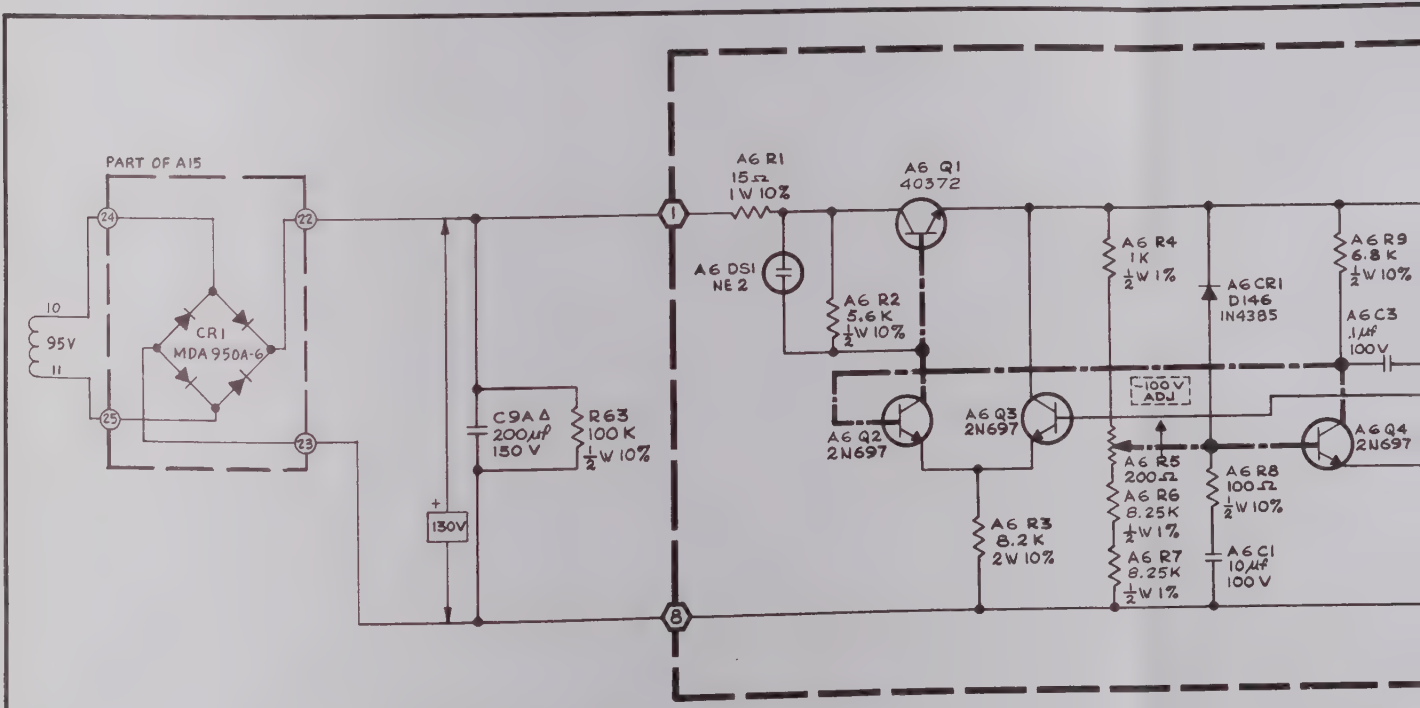
FIGURE 4-10
PROTECTION CIRCUITS



ALTERNATE PLUG-IN UNIT CIRCUIT FOR VTM UNITS



IN S/N 1090 AND BELOW, CR9 THRU CR12 ON MAIN CHASSIS ARE USED INSTEAD OF A15CR2



IN S/N 1090 AND BELOW, CR13 THRU CR16 ON MAIN CHASSIS ARE USED INSTEAD OF A15CR1

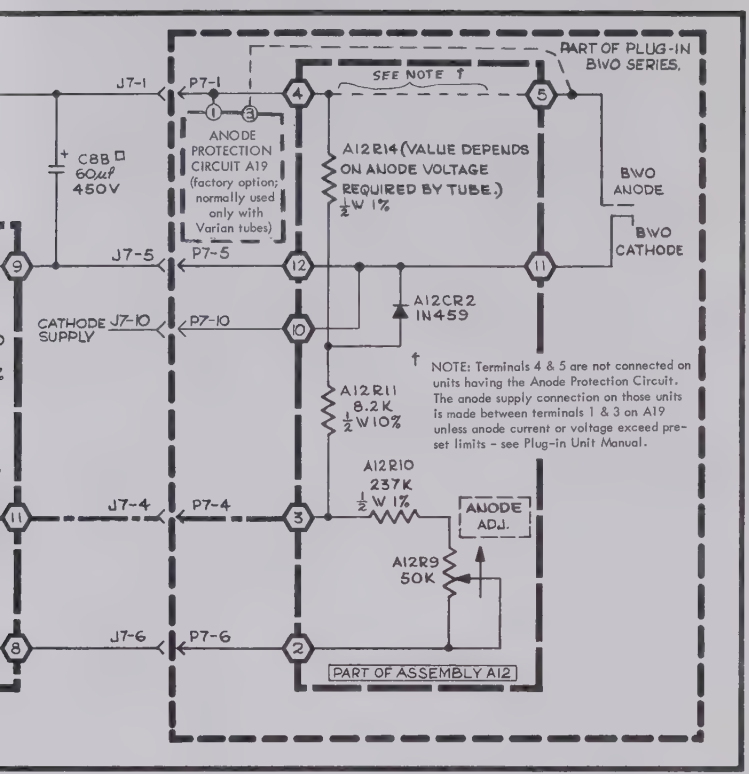

PART OF PLUG-IN BWO SERIES.
SEE NOTE †
J7-1
P7-1
C8B □ 60μf 450V
ANODE PROTECTION CIRCUIT A19 (factory option; normally used only with Varian tubes)
A12R14 (VALUE DEPENDS ON ANODE VOLTAGE REQUIRED BY TUBE.) ½W 1%
BWO ANODE
BWO CATHODE
J7-5
P7-5
CATHODE SUPPLY
J7-10
P7-10
A12CR2 IN459
† NOTE: Terminals 4 & 5 are not connected on units having the Anode Protection Circuit. The anode supply connection on those units is made between terminals 1 & 3 on A19 unless anode current or voltage exceed preset limits – see Plug-in Unit Manual.
A12R11 8.2K ½W 10%
A12R10 237K ½W 1%
J7-4
P7-4
ANODE ADJ.
A12R9 50K
J7-6
P7-6
PART OF ASSEMBLY A12

FIGURE 4-11
ANODE SUPPLY

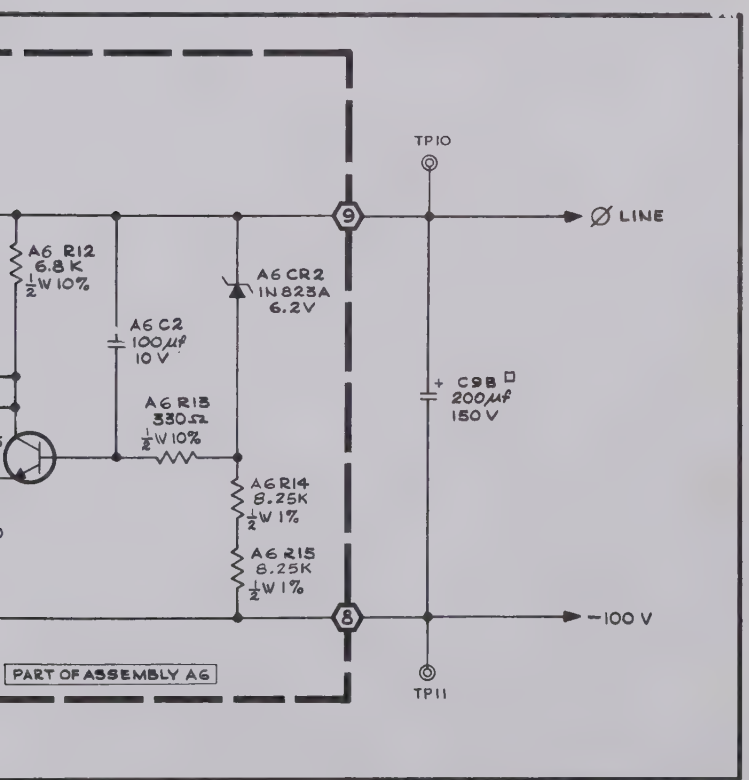
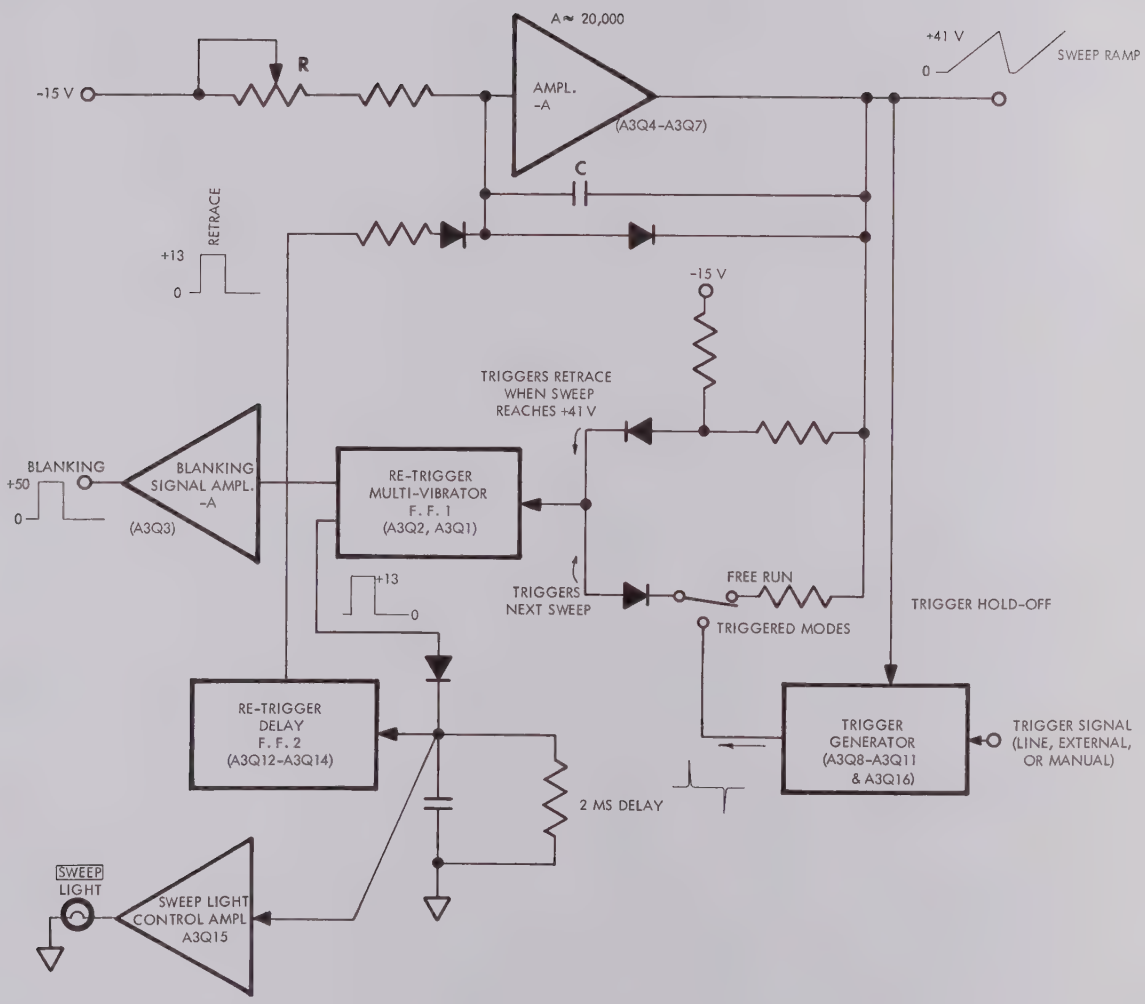
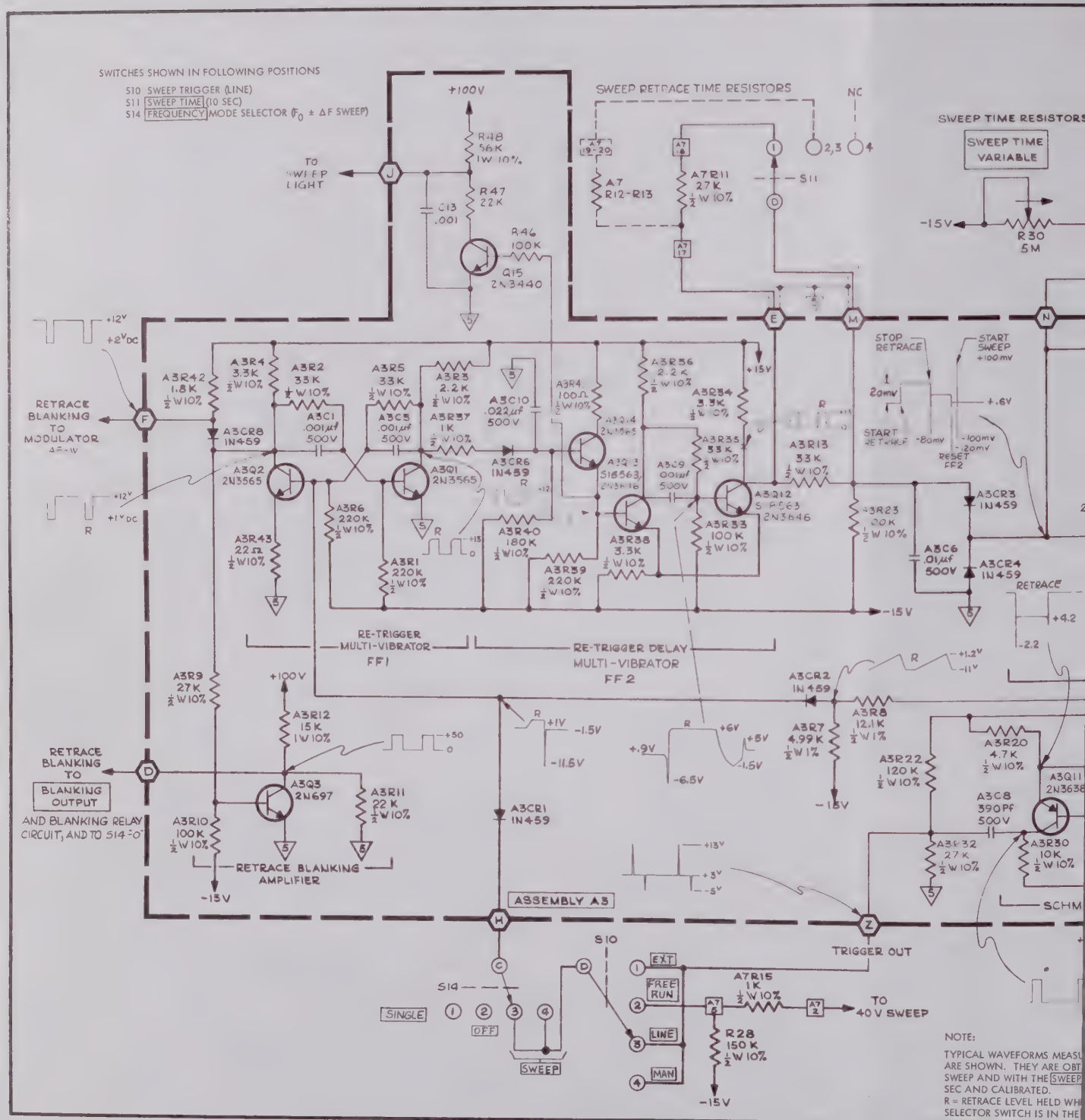


FIGURE 4-12
-100 VOLT SUPPLY



BLOCK DIAGRAM OF SWEEP GENERATOR A3



Revised 2/15/68

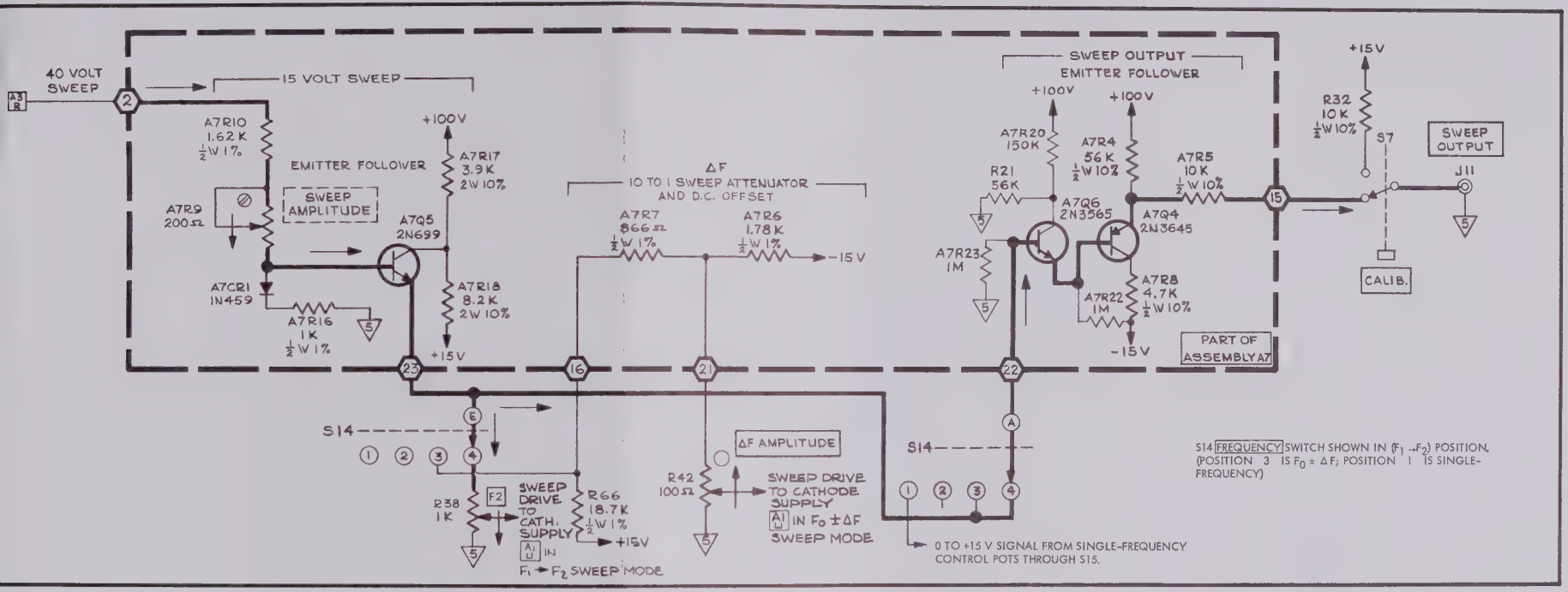


FIGURE 4-14
SWEEP OUTPUT CIRCUIT

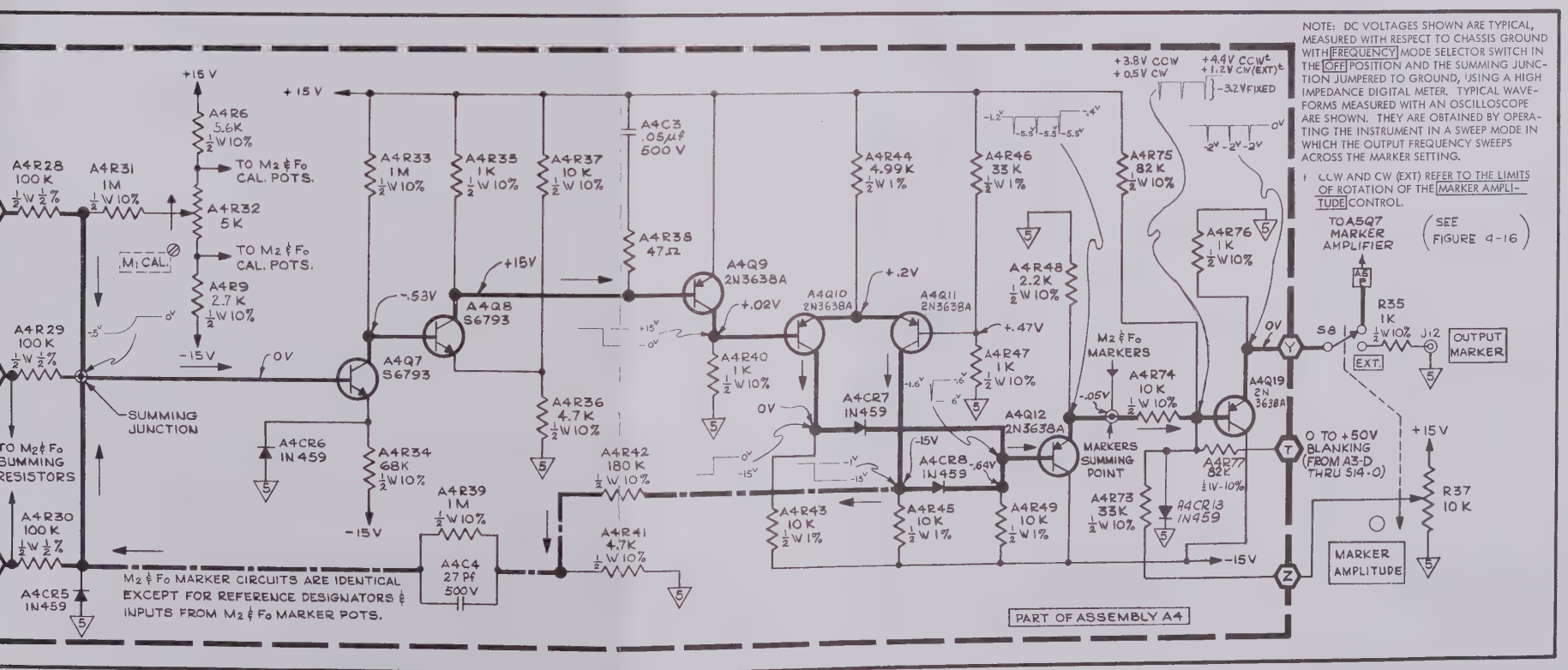
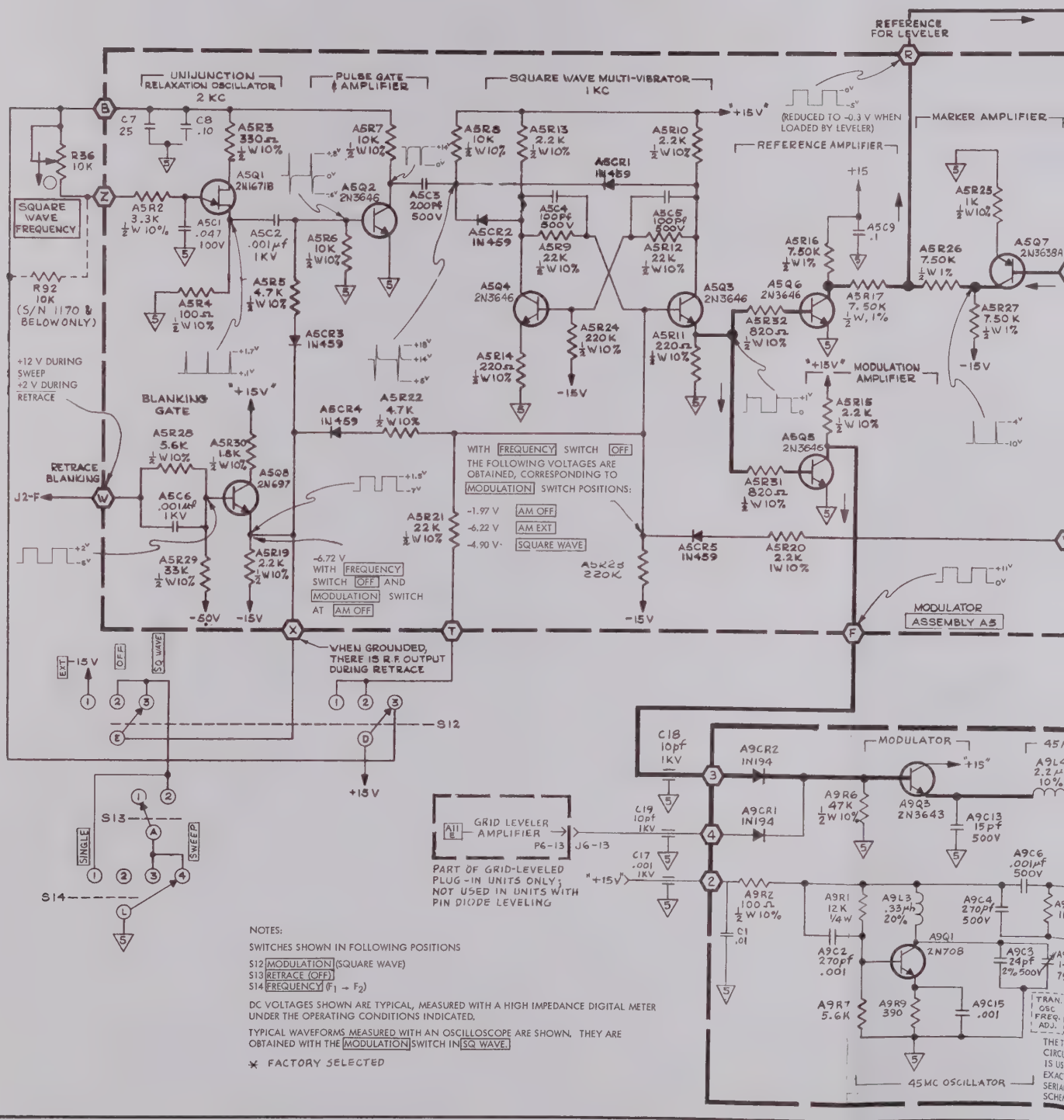

NOTE: DC VOLTAGES SHOWN ARE TYPICAL, MEASURED WITH RESPECT TO CHASSIS GROUND WITH FREQUENCY MODE SELECTOR SWITCH IN THE OFF POSITION AND THE SUMMING JUNCTION JUMPERED TO GROUND, USING A HIGH IMPEDANCE DIGITAL METER. TYPICAL WAVEFORMS MEASURED WITH AN OSCILLOSCOPE ARE SHOWN. THEY ARE OBTAINED BY OPERATING THE INSTRUMENT IN A SWEEP MODE IN WHICH THE OUTPUT FREQUENCY SWEEPS ACROSS THE MARKER SETTING.
† CCW AND CW (EXT) REFER TO THE LIMITS OF ROTATION OF THE MARKER AMPLITUDE CONTROL.
+15 V
A4R6 5.6K ½W 10%
A4R28 100K ½W ½%
A4R31 1M ½W 10%
TO M2 & Fo CAL. POTS.
A4R32 5K
TO M2 & Fo CAL. POTS.
M1 CAL.
A4R9 2.7K ½W 10%
A4R29 100K ½W ½%
-15V
0V
SUMMING JUNCTION
TO M2 & Fo SUMMING RESISTORS
A4R30 100K ½W ½%
A4CR5 IN459
A4R33 1M ½W 10%
A4R35 1K ½W 10%
A4R37 10K ½W 10%
A4C3 .05μf 500 V
A4R38 47Ω
A4Q8 S6793
-.53V
A4Q7 S6793
A4R34 68K ½W 10%
A4CR6 IN459
A4R36 4.7K ½W 10%
A4R39 1M ½W 10%
A4C4 27 Pf 500V
A4R42 180 K ½W 10%
A4R41 4.7K ½W 10%
A4Q9 2N3638A
+.02V
A4Q10 2N3638A
A4Q11 2N3638A
+.2V
+.47V
A4R40 1K ½W 10%
A4R47 1K ½W 10%
A4CR7 IN459
A4Q12 2N3638A
A4R43 10K ½W 1%
A4R45 10K ½W 1%
A4R49 10K ½W 1%
A4R44 4.99K ½W 1%
A4R46 33K ½W 1%
A4R48 2.2K ½W 10%
A4R75 82K ½W 10%
A4R76 1K ½W 10%
+3.8V CCW +0.5V CW
+4.4V CCW† +1.2V CW(EXT)†
-3.2V FIXED
TO A5Q7 MARKER AMPLIFIER
(SEE FIGURE 4-16)
A5
R35 1K ½W 10%
S8
J12
OUTPUT MARKER
EXT.
M2 & Fo MARKERS
A4R74 10K ½W 10%
-.05V
MARKERS SUMMING POINT
A4Q19 2N3638A
A4R77 82K ½W 10%
A4R73 33K ½W 10%
A4CR13 IN459
0 TO +50V BLANKING (FROM A3-D THRU S14-0)
+15V
R37 10K
MARKER AMPLITUDE
-15V
M2 & Fo MARKER CIRCUITS ARE IDENTICAL EXCEPT FOR REFERENCE DESIGNATORS & INPUTS FROM M2 & Fo MARKER POTS.
PART OF ASSEMBLY A4

FIGURE 4-15
MARKER GENERATOR

Revised 2/15/68



NOTES:

SWITCHES SHOWN IN FOLLOWING POSITIONS

S12 MODULATION (SQUARE WAVE)
S13 RETRACE (OFF)
S14 FREQUENCY ($F_1 \rightarrow F_2$)

DC VOLTAGES SHOWN ARE TYPICAL, MEASURED WITH A HIGH IMPEDANCE DIGITAL METER UNDER THE OPERATING CONDITIONS INDICATED.

TYPICAL WAVEFORMS MEASURED WITH AN OSCILLOSCOPE ARE SHOWN. THEY ARE OBTAINED WITH THE MODULATION SWITCH IN SQ WAVE.

* FACTORY SELECTED

Revised 2/15/68

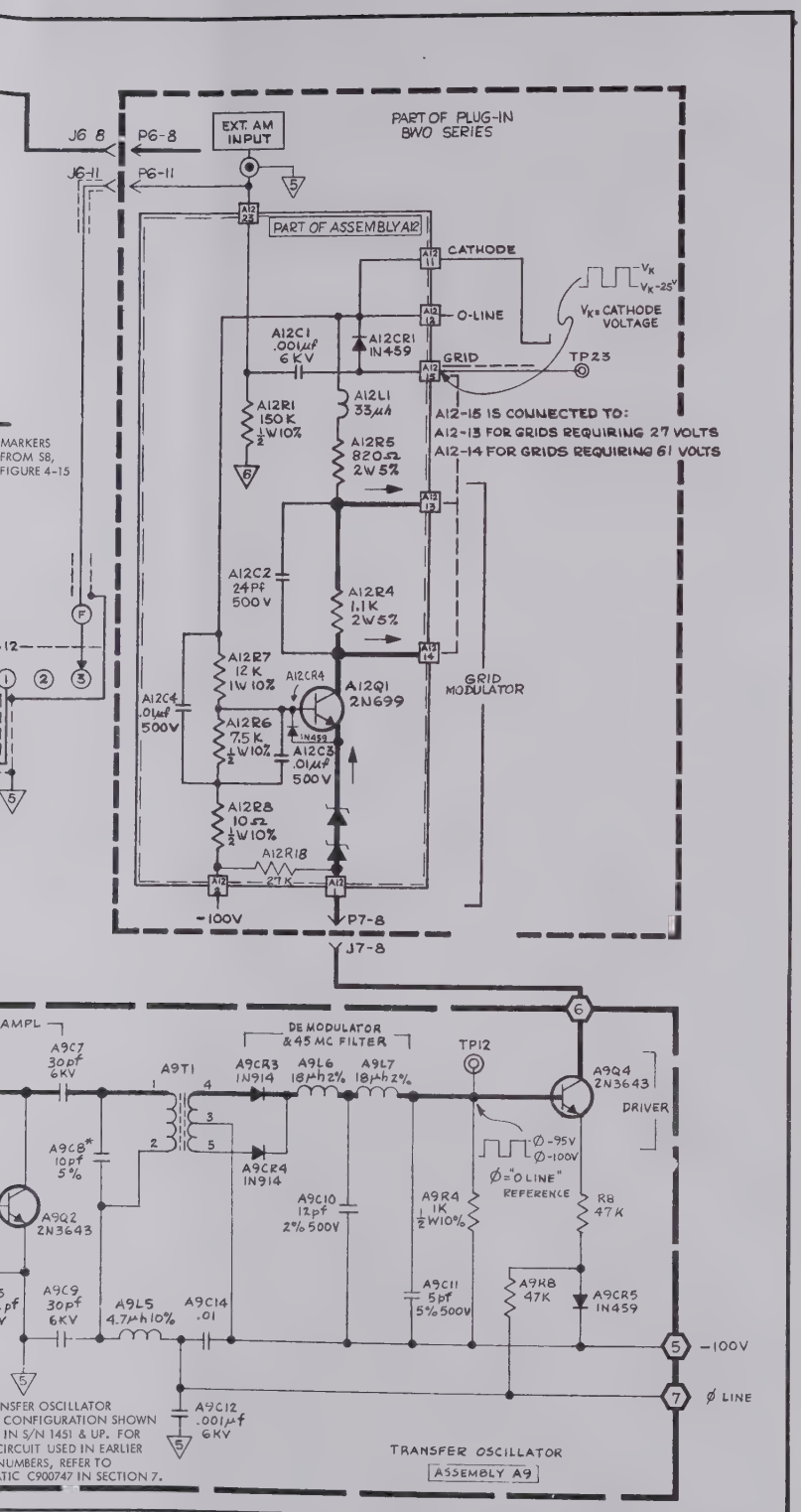
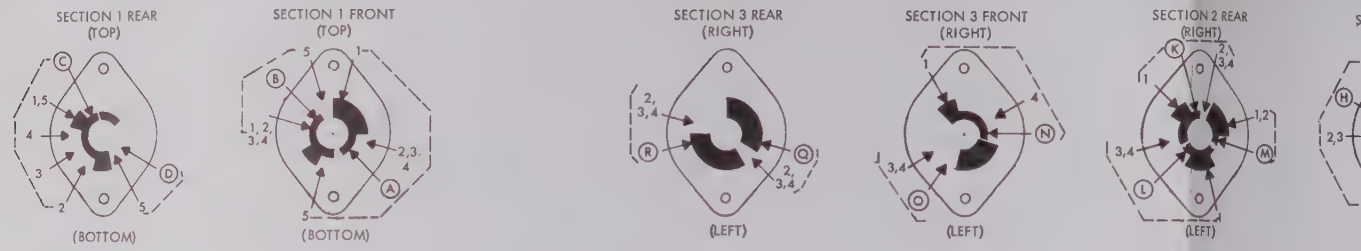


FIGURE 4-16
MODULATOR AND TRANSFER OSCILLATOR CIRCUITS

IT [VIEWED AND SECTION-NUMBERED
N-CODED TERMINAL NUMBERS REFER
OWN IN EXTREME CCW PSN (PSN #1)]

S14 SWITCH PHYSICAL ARRANGEMENT [VIEWED AND SECT
SWITCH-POSITION-CODED TERMINAL NUMBERS REFER TO SCHEM
CCW PSN (PSN #1)]



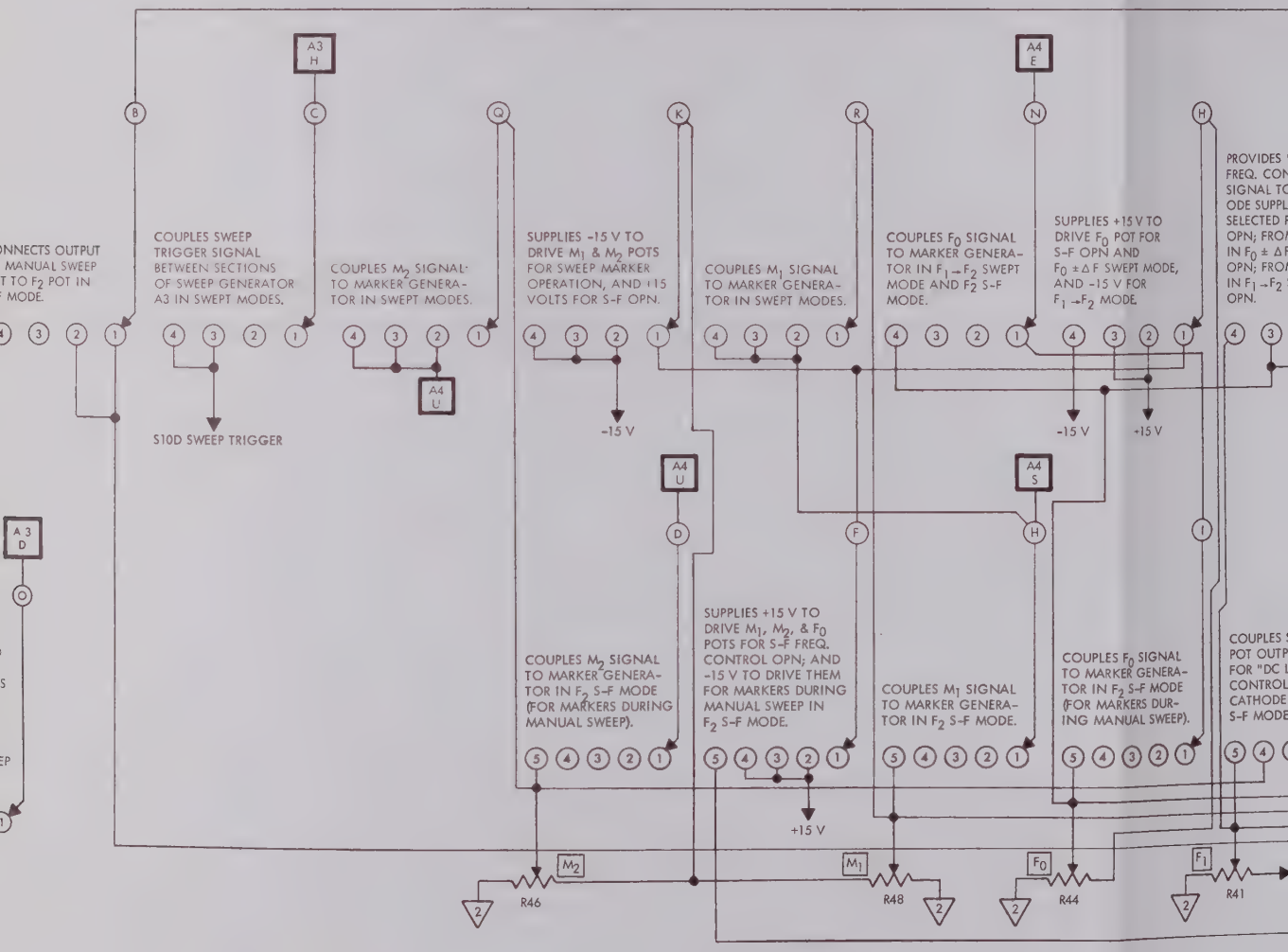
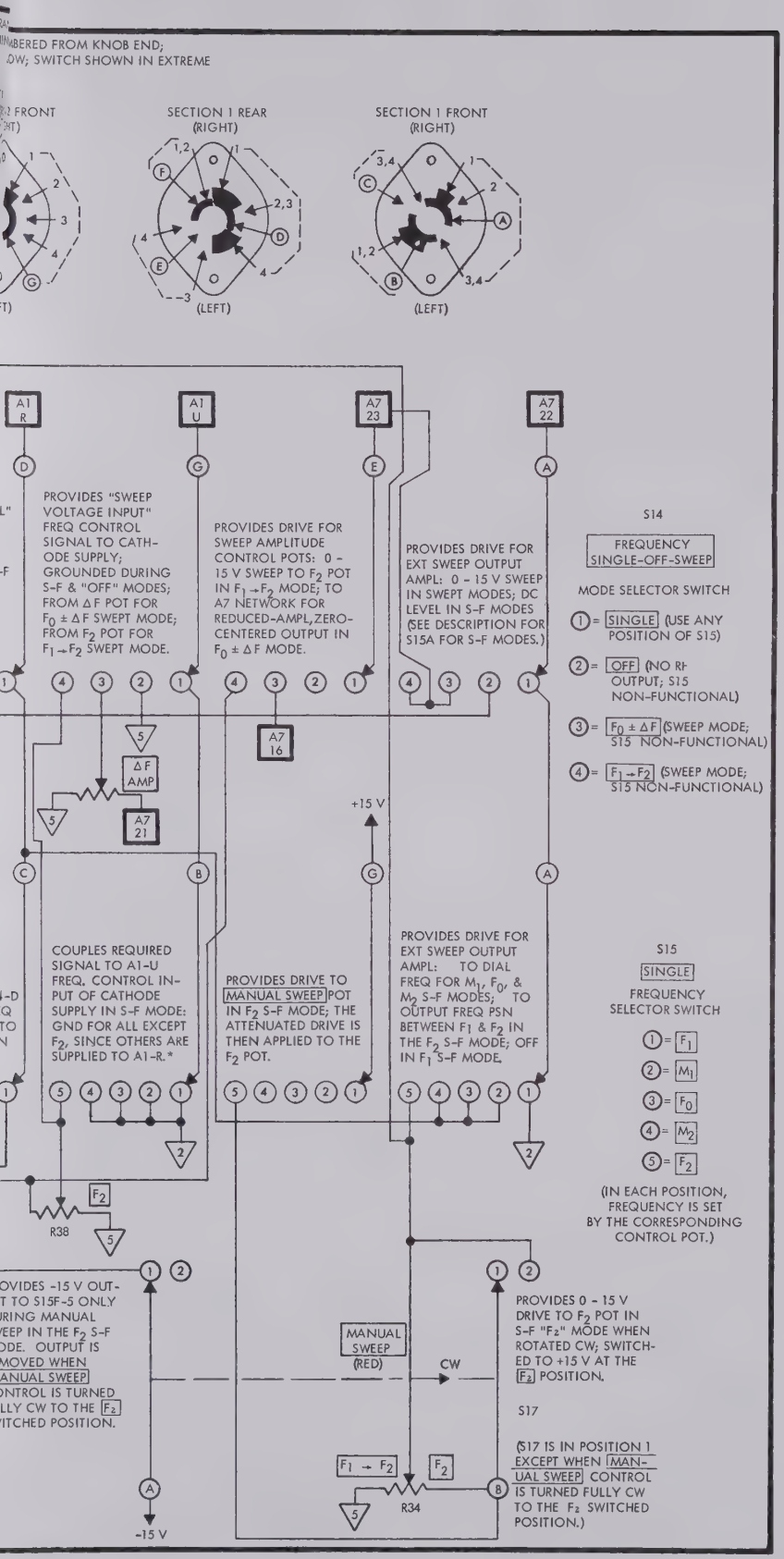

A3 H
A4 E
A4 U
A4 S
A3 D
COUPLES SWEEP TRIGGER SIGNAL BETWEEN SECTIONS OF SWEEP GENERATOR A3 IN SWEPT MODES.
S10D SWEEP TRIGGER
COUPLES M_2 SIGNAL TO MARKER GENERATOR IN SWEPT MODES.
SUPPLIES -15 V TO DRIVE M_1 & M_2 POTS FOR SWEEP MARKER OPERATION, AND +15 VOLTS FOR S-F OPN.
-15 V
COUPLES M_1 SIGNAL TO MARKER GENERATOR IN SWEPT MODES.
COUPLES F_0 SIGNAL TO MARKER GENERATOR IN $F_1 \rightarrow F_2$ SWEPT MODE AND F_2 S-F MODE.
SUPPLIES +15 V TO DRIVE F_0 POT FOR S-F OPN AND $F_0 \pm \Delta F$ SWEPT MODE, AND -15 V FOR $F_1 \rightarrow F_2$ MODE.
-15 V
+15 V
COUPLES M_2 SIGNAL TO MARKER GENERATOR IN F_2 S-F MODE (FOR MARKERS DURING MANUAL SWEEP).
SUPPLIES +15 V TO DRIVE M_1, M_2, & F_0 POTS FOR S-F FREQ. CONTROL OPN; AND -15 V TO DRIVE THEM FOR MARKERS DURING MANUAL SWEEP IN F_2 S-F MODE.
+15 V
COUPLES M_1 SIGNAL TO MARKER GENERATOR IN F_2 S-F MODE.
COUPLES F_0 SIGNAL TO MARKER GENERATOR IN F_2 S-F MODE (FOR MARKERS DURING MANUAL SWEEP).
R46
R48
R44
R41

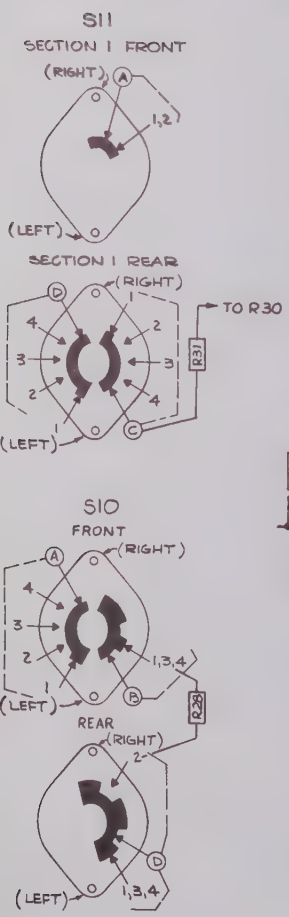
**FIGURE 4-17. S
SELECTOR SW**


ABERED FROM KNOB END;
OW; SWITCH SHOWN IN EXTREME
2 FRONT
HT)
SECTION 1 REAR
(RIGHT)
SECTION 1 FRONT
(RIGHT)
(LEFT)
(LEFT)
A1
R
A1
U
A7
23
A7
22
PROVIDES "SWEEP VOLTAGE INPUT" FREQ CONTROL SIGNAL TO CATHODE SUPPLY; GROUNDED DURING S-F & "OFF" MODES; FROM ΔF POT FOR F0 ± ΔF SWEPT MODE; FROM F2 POT FOR F1 → F2 SWEPT MODE.
PROVIDES DRIVE FOR SWEEP AMPLITUDE CONTROL POTS: 0 - 15 V SWEEP TO F2 POT IN F1 → F2 MODE; TO A7 NETWORK FOR REDUCED-AMPL, ZERO-CENTERED OUTPUT IN F0 ± ΔF MODE.
PROVIDES DRIVE FOR EXT SWEEP OUTPUT AMPL: 0 - 15 V SWEEP IN SWEPT MODES; DC LEVEL IN S-F MODES (SEE DESCRIPTION FOR S15A FOR S-F MODES.)
S14
FREQUENCY
SINGLE-OFF-SWEEP
MODE SELECTOR SWITCH
1 = SINGLE (USE ANY POSITION OF S15)
2 = OFF (NO RF OUTPUT; S15 NON-FUNCTIONAL)
3 = F0 ± ΔF (SWEEP MODE; S15 NON-FUNCTIONAL)
4 = F1 → F2 (SWEEP MODE; S15 NON-FUNCTIONAL)
ΔF AMP
A7 21
A7 16
+15 V
COUPLES REQUIRED SIGNAL TO A1-U FREQ. CONTROL INPUT OF CATHODE SUPPLY IN S-F MODE: GND FOR ALL EXCEPT F2, SINCE OTHERS ARE SUPPLIED TO A1-R.*
PROVIDES DRIVE TO MANUAL SWEEP POT IN F2 S-F MODE; THE ATTENUATED DRIVE IS THEN APPLIED TO THE F2 POT.
PROVIDES DRIVE FOR EXT SWEEP OUTPUT AMPL: TO DIAL FREQ FOR M1, F0, & M2 S-F MODES; TO OUTPUT FREQ PSN BETWEEN F1 & F2 IN THE F2 S-F MODE; OFF IN F1 S-F MODE.
S15
SINGLE
FREQUENCY SELECTOR SWITCH
1 = F1
2 = M1
3 = F0
4 = M2
5 = F2
(IN EACH POSITION, FREQUENCY IS SET BY THE CORRESPONDING CONTROL POT.)
F2
R38
OVIDES -15 V OUT-
T TO S15F-5 ONLY
URING MANUAL
EEP IN THE F2 S-F
DE. OUTPUT IS
MOVED WHEN
ANUAL SWEEP
ONTROL IS TURNED
LLY CW TO THE F2
ITCHED POSITION.
MANUAL SWEEP (RED)
CW
PROVIDES 0 - 15 V DRIVE TO F2 POT IN S-F "F2" MODE WHEN ROTATED CW; SWITCHED TO +15 V AT THE F2 POSITION.
S17
(S17 IS IN POSITION 1 EXCEPT WHEN MANUAL SWEEP CONTROL IS TURNED FULLY CW TO THE F2 SWITCHED POSITION.)
F1 → F2
F2
R34
-15 V

MATIC AND WIRING DIAGRAM OF FREQUENCY MODE
H S14 AND SINGLE FREQUENCY SELECTOR SWITCH S15

PHYSICAL ARRANGEMENT OF SWITCHES:

[VIEWED FROM KNOB ENDS; SWITCH-POSITION-CODED TERMINAL NUMBERS REFER TO SCHEMATICS AT RIGHT AND SWITCHES SHOWN IN EXTREME CCW POSITION (PSN #1)]



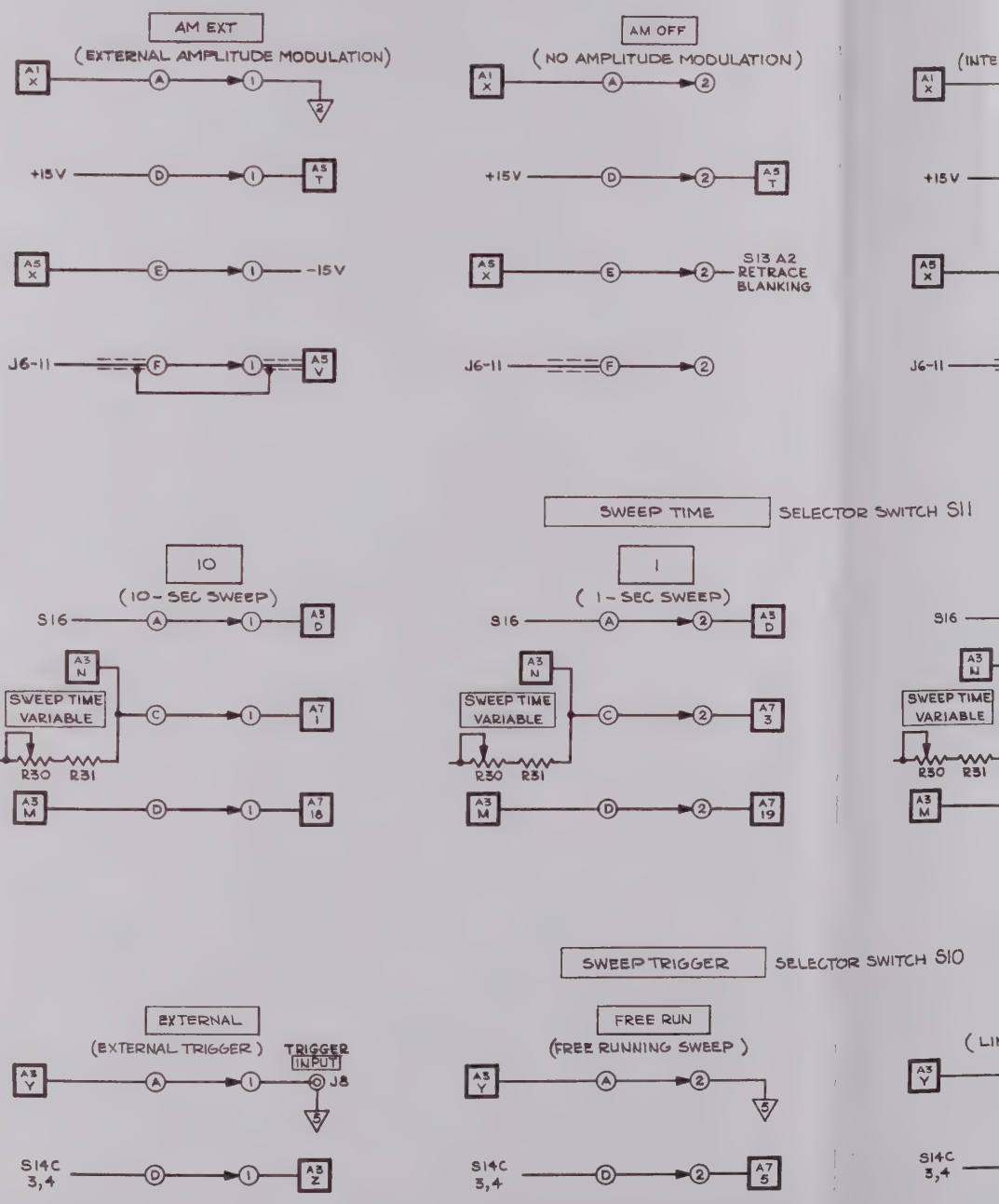
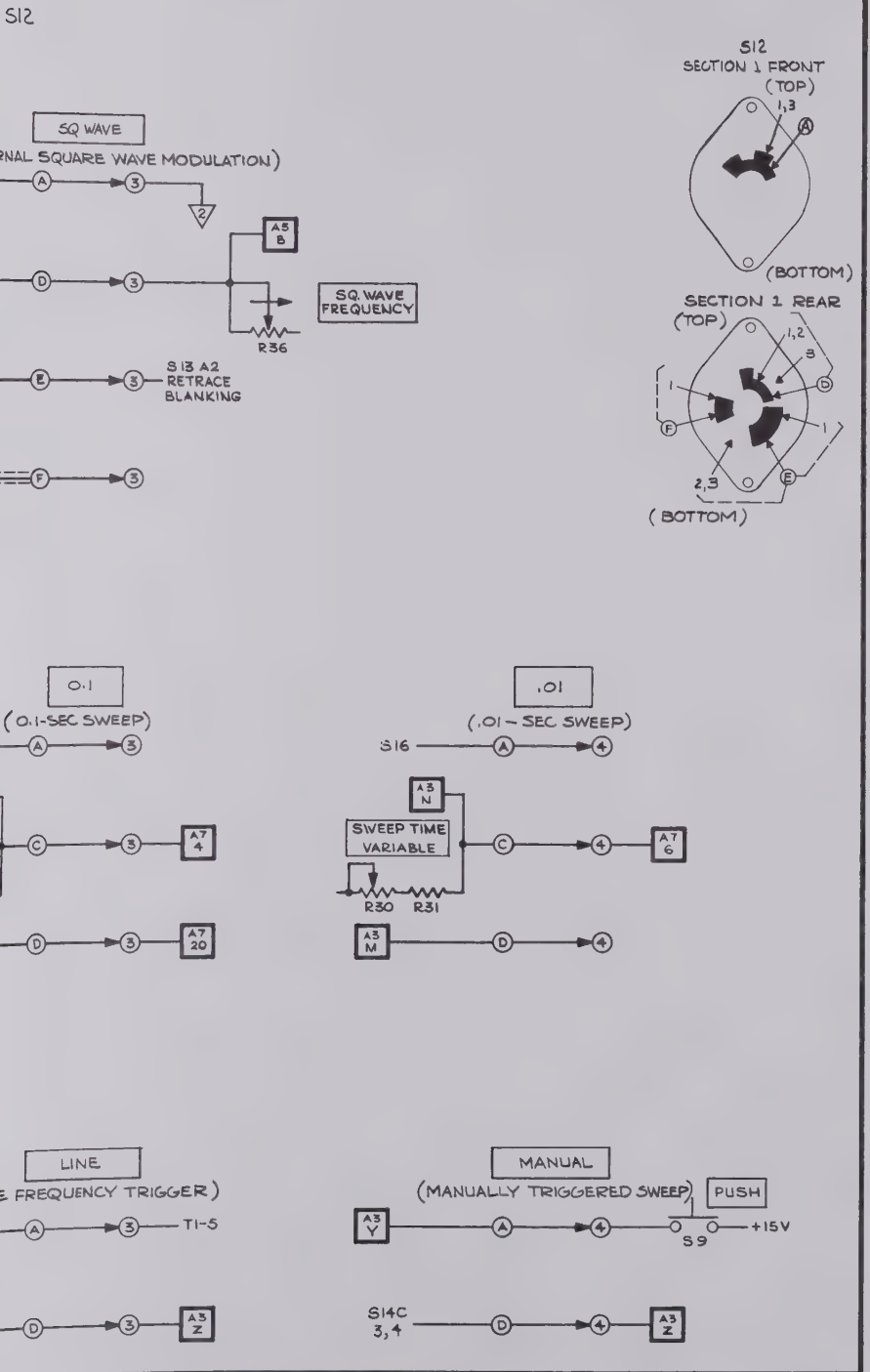


FIGURE 4
SWEEP TI



18. SCHEMATIC AND WIRING DIAGRAM OF MODULATION, E AND SWEEP TRIGGER SELECTOR SWITCHES

SECTION 5

MAINTENANCE

5.1 PERIODIC MAINTENANCE.

Every few months perform the following maintenance on the Model 650.

a. Remove all accumulated dust with forced air.

b. Visually inspect the unit for loose or broken connections, loose panel controls or connectors, improperly seated tubes, bent or broken tube pins, etc. Replace worn-out components as required.

c. Check voltages at test points as directed in Paragraph 5.2.

d. Make a performance test in accordance with the procedure of Paragraph 2.7.

CAUTION

Do not attempt to "cheat" the plug-in interlock or to energize the Model 650 with no plug-in unit installed.
All required lubrication is performed at the factory during assembly. Field lubrication should not be required.

5.2 VOLTAGE MEASUREMENTS AT CHASSIS TEST POINTS.

Test points are provided on the Model 650 chassis at the outputs of all the low and high voltage supplies and at the output of the transfer oscillator, as shown in Figures 5-1, 5-2, and 5-3. Test points are provided at the accessible side of the plug-in unit for measurement of the tube electrode voltages. Test points on a typical plug-in unit containing a BWO tube are visible in Figure 5-3. Each plug-in unit containing a VTM has a single voltage test point, TP21 INJECTOR, and most VTM plug-in units also have TP22, HEATER CURRENT.

A check of the supply outputs should be made as the first step in a routine performance check or in locating the cause of malfunction. The low voltage supplies, listed in Group 1 of Table 5-1, should be checked first, since the high voltage supplies and most other circuits of the instrument cannot operate properly with out-of-spec low voltages. The low voltage test points are located on the right-hand side of the chassis (Figure 5-2). These voltages are measured with respect to chassis ground (TP3), and any accurate digital meter can be used.

The high voltage test points, listed in Groups 2 and 3 of Table 5-1, are located on the left-hand side of the chassis (Figure 5-3). TP12, the transfer oscillator output, is located nearby on the top of the chassis (Figure 5-1).

The cathode supply output (TP6) is measured with respect to chassis ground, and a high-voltage voltmeter or a high-voltage probe must be used. For all other high voltage measurements, the "0 line" (TP10) which is at or near cathode potential is the reference rather than chassis ground, and a floating voltmeter with at least 3000 volts insulation must be used. The heater supply output between TP7 and TP8 may be measured with high voltage off, using a standard meter. The lowest cathode supply output voltage, which in some plug-in units is low enough for measurement without an insulated meter, is obtained with a single-frequency setting at the low end of the band. Other high voltage measurements should be made at this setting of the cathode supply to keep the "0 line" voltage as low as possible for safety reasons.

Refer to the plug-in unit manual for instructions concerning measurements of HELIX and COLLECTOR currents on BWO tubes at TP21 and TP22.

5.3 INTERNAL ADJUSTMENTS.

CAUTION

Before attempting to make ANY adjustments of chassis calibration controls, read all the material under this heading. Improper adjustments can degrade the accuracy of the instrument.

5.3.1 AVAILABLE ADJUSTMENTS. There are 17 internal adjustments in the Model 650. The instrument is designed for long-term operation with a minimum of adjustment. The factory calibration is carefully standardized so that all rf plug-in units can be used interchangeably without requiring any readjustment whatsoever. The 17 adjustments include 11 "critical" adjustments which should not need field adjustment unless components are replaced in the critical circuits calibrated by these adjustments. The other six adjustments can be used for periodic recalibration at six-month intervals or as required. These two different classes of adjustments, and their uses, are described separately in Paragraphs 5.3.2 and 5.3.3.

5.3.2 CRITICAL ADJUSTMENTS. The critical adjustments can degrade factory calibration accuracy, and/or affect interchangeability of plug-in units if adjusted without specialized calibration techniques. These critical adjustments are located in stabilized circuits protected against in-service component variations. They should not require any further adjustment in the field unless damage or component failure occurs in the critical circuits calibrated by these adjustments. If calibration is required because of replacement of parts in a critical circuit, the optimum manner of performing the critical adjustments is to obtain a Sweep Oscillator Calibration Plug-in unit, Model 650T. This plug-in unit permits calibration in accordance with factory-approved procedures, using calibrated voltmeters and oscilloscopes for test monitoring. Complete procedures for factory-type calibration of the Model 650 are included in the instruction manual for the Model 650T.

When a Model 650T plug-in unit is not available, field adjustments can be made with an rf plug-in unit installed, checking for proper tube drive voltages and rf output frequencies. However, the adjustments thus made may be satisfactory only for the one rf plug-in unit used for calibration. This is because (1) The adjustments made will probably differ somewhat from the "standard" factory adjustment which has a smaller tolerance than any individual plug-in unit to place performance throughout the operating range within the specification tolerance of all plug-in units; (2) The plug-in unit used for calibration may not utilize the full range of the Model 650 supply outputs, meaning that the calibration would be performed in the center of the total range, and not at the limits; (3) If improper adjustments had previously been made on the rf plug-in unit used for calibration, the "calibration" adjustments made on the Model 650 would actually be incorrect, since they would be compensating for an improperly calibrated plug-in unit.

Thus, field calibration performed using a particular rf plug-in unit as a calibration standard may still cause other plug-in units to operate outside of specifications by an amount that can most accurately be determined by actual test. If the rf plug-in unit used for calibration is itself properly adjusted, and if the other plug-ins being used utilize the same range of the Model

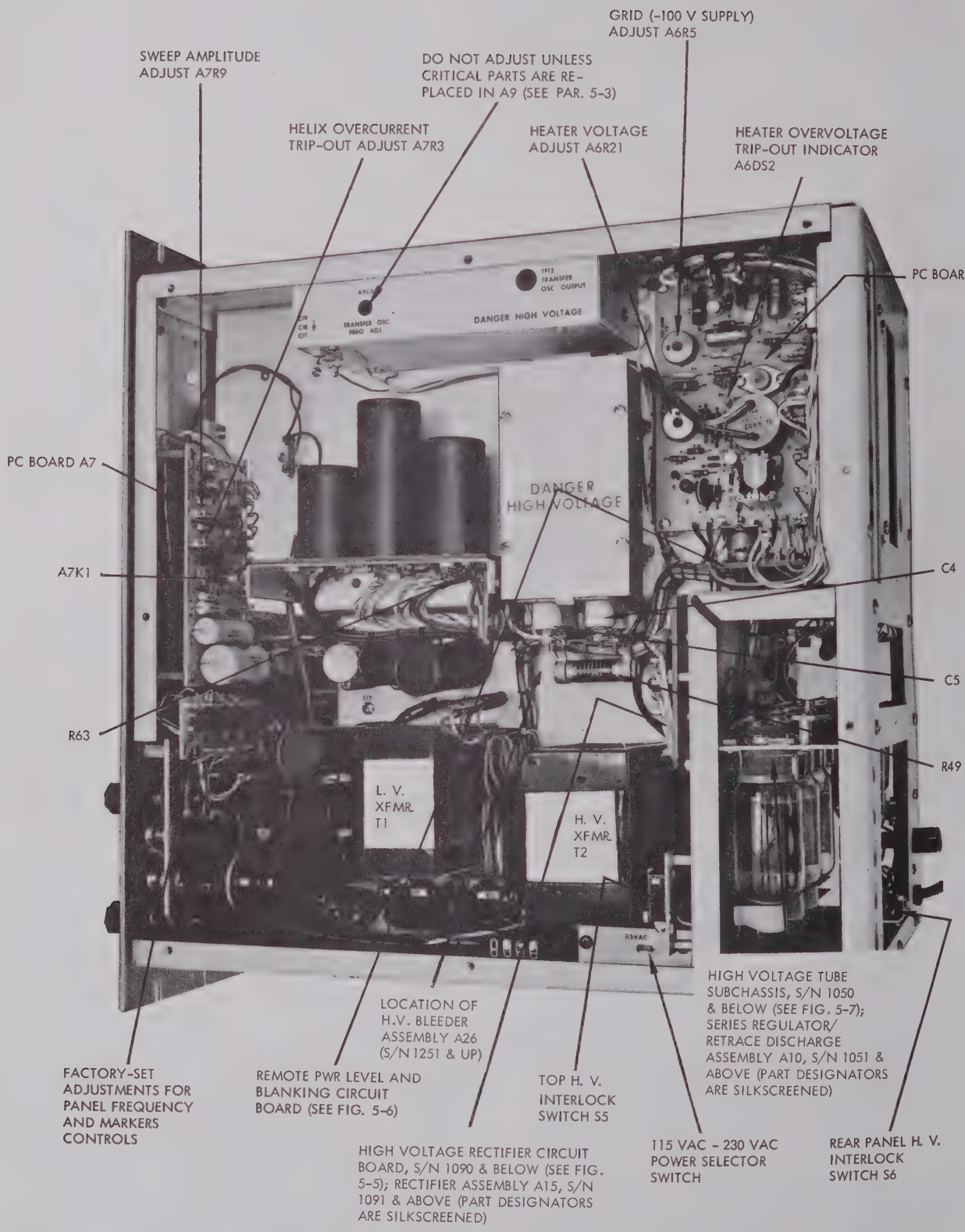

GRID (-100 V SUPPLY) ADJUST A6R5
SWEEP AMPLITUDE ADJUST A7R9
DO NOT ADJUST UNLESS CRITICAL PARTS ARE RE-PLACED IN A9 (SEE PAR. 5-3)
HELIX OVERCURRENT TRIP-OUT ADJUST A7R3
HEATER VOLTAGE ADJUST A6R21
HEATER OVERVOLTAGE TRIP-OUT INDICATOR A6DS2
PC BOARD A6
PC BOARD A7
A7K1
R63
C4
C5
R49
DANGER HIGH VOLTAGE
L. V. XFMR. T1
H. V. XFMR. T2
TRANSFER OSC FREQ ADJ
DANGER HIGH VOLTAGE
115VAC
FACTORY-SET ADJUSTMENTS FOR PANEL FREQUENCY AND MARKERS CONTROLS
REMOTE PWR LEVEL AND BLANKING CIRCUIT BOARD (SEE FIG. 5-6)
LOCATION OF H.V. BLEEDER ASSEMBLY A26 (S/N 1251 & UP)
HIGH VOLTAGE RECTIFIER CIRCUIT BOARD, S/N 1090 & BELOW (SEE FIG. 5-5); RECTIFIER ASSEMBLY A15, S/N 1091 & ABOVE (PART DESIGNATORS ARE SILKSCREENED)
TOP H. V. INTERLOCK SWITCH S5
HIGH VOLTAGE TUBE SUBCHASSIS, S/N 1050 & BELOW (SEE FIG. 5-7); SERIES REGULATOR/ RETRACE DISCHARGE ASSEMBLY A10, S/N 1051 & ABOVE (PART DESIGNATORS ARE SILKSCREENED)
115 VAC - 230 VAC POWER SELECTOR SWITCH
REAR PANEL H. V. INTERLOCK SWITCH S6

FIGURE 5-1. TOP VIEW OF CHASSIS

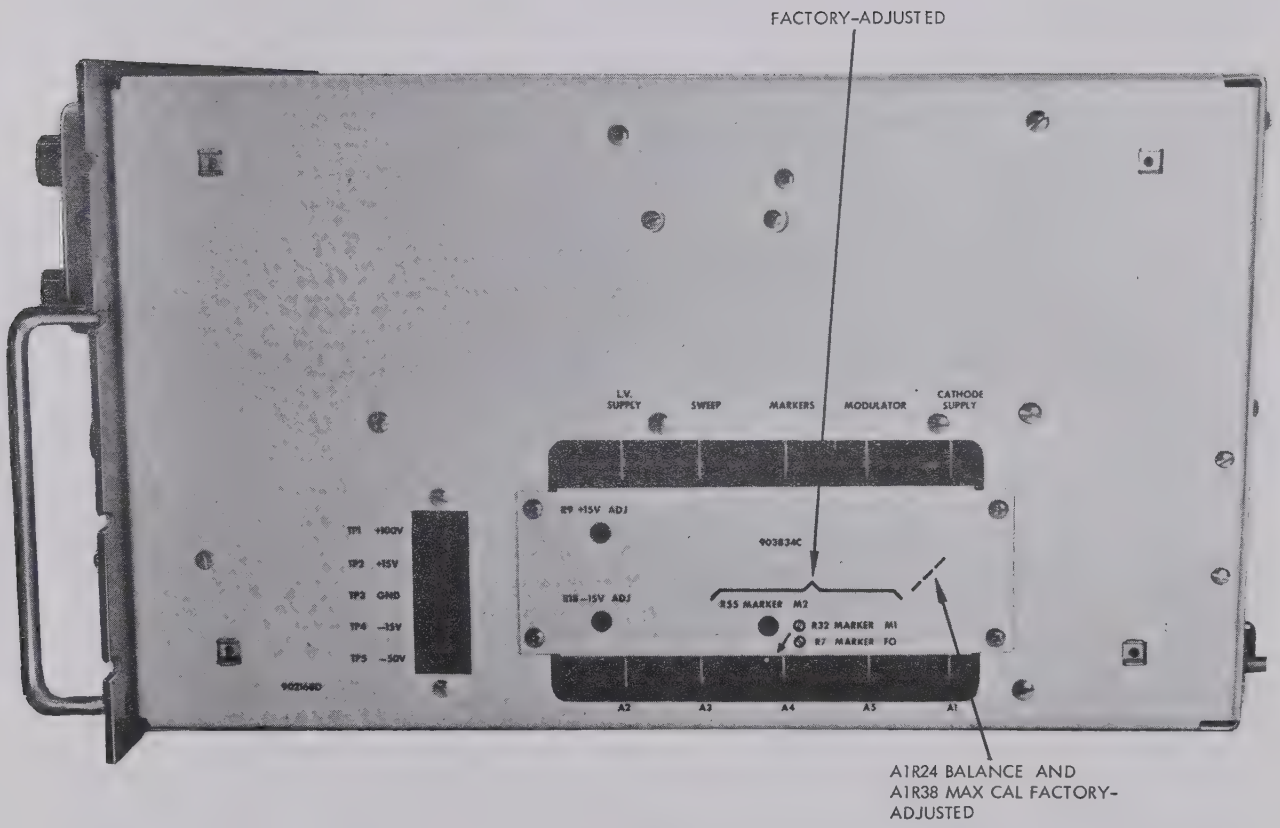


FIGURE 5-2. RIGHT-SIDE VIEW OF CHASSIS

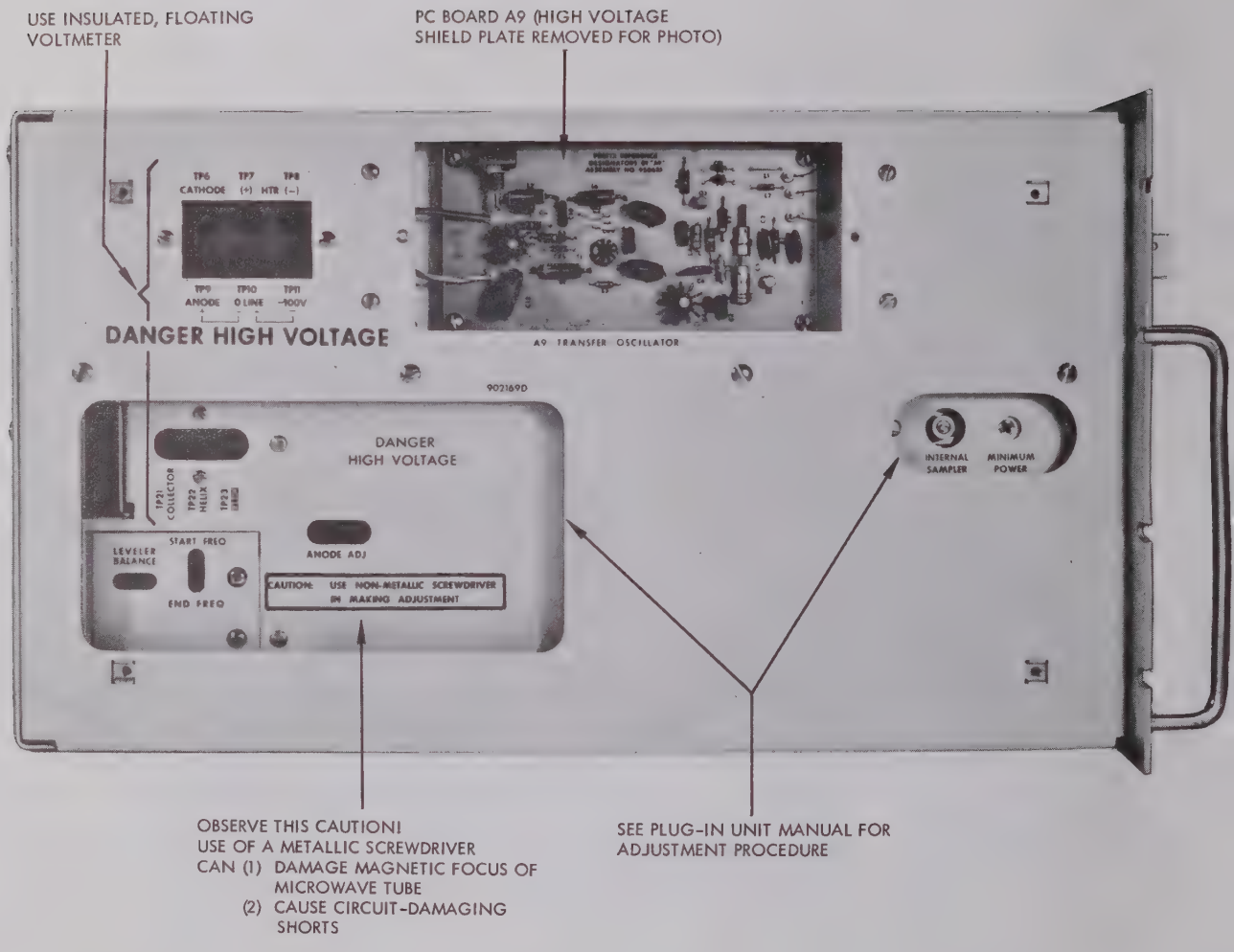


FIGURE 5-3. LEFT-SIDE VIEW OF CHASSIS WITH TYPICAL PLUG-IN INSTALLED

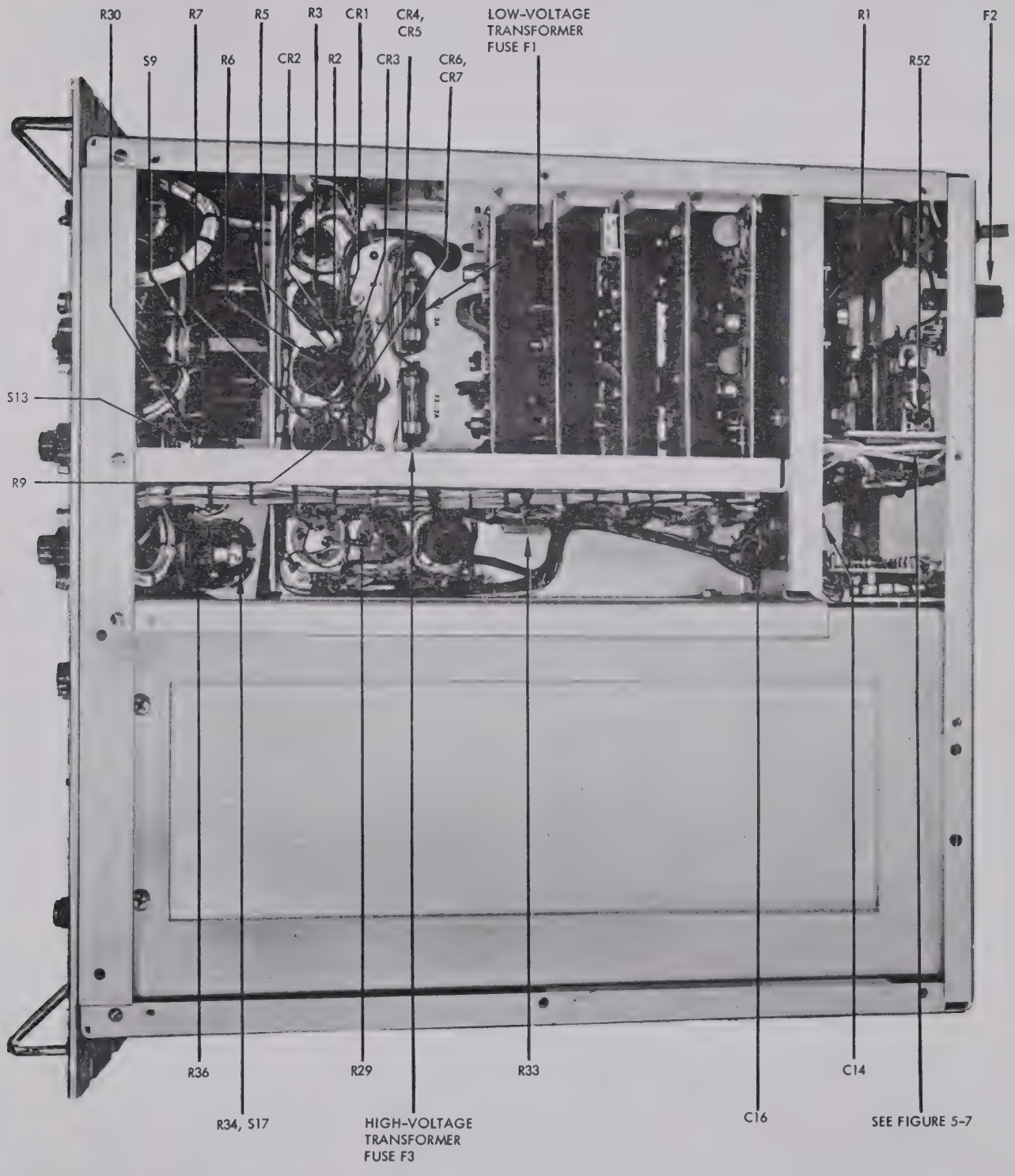


FIGURE 5-4. BOTTOM VIEW OF CHASSIS

Table 5-1. Test Point Measurements

GROUP 1 - Measured with Respect to Ground (TP3) with Standard Digital Meter (Listed in Preferred Order of Measurement).

Supply	TP#	DC Voltage & Tolerance	AC Ripple
-15 V*	TP4	-15.0000 ± 0.0075 V	500 μv maximum
+15 V*	TP2	+15.0000 ± 0.0075 V	500 μv maximum
+100 V	TP1	+100.0 ± 3.0 V	2 mv maximum
-50 V	TP4	-50 ± 5 V	2 mv maximum

GROUP 2 - Measured with Respect to Ground (TP3 or Chassis) with High Voltage Digital Meter or Suitable Voltage-Divider Probe.

Supply	TP#	DC Voltage & Tolerance	AC Ripple
Cathode	TP6	(-150 to -2500 V; refer to plug-in unit manual for the specific range.)	(refer to plug-in unit manual)

GROUP 3 - Measured Between Two Test Points, Requiring Use of a Floating, Insulated Voltmeter (Listed in Preferred Order of Measurement).

Supply	TP# to TP#	Voltage	Notes
Heater* (voltage)	TP7 (+) TP8 (-)	6.3 V ± 0.1 V (with 1 ampere load)	Measure with high-voltage off.
-100 V*	TP10 (+) TP11 (-)	100 ± 0.1 V	FREQUENCY Mode Selector switch on SINGLE, no modulation
Anode	TP9 (+) TP10 (-)	30 to 280 V, depending upon plug-in unit used.**	Voltage is set by means of feedback controlled by a factory-selected resistor in each plug-in unit. (See Figure 5-8.)
Transfer Oscillator Output	TP12 (+) TP11 (-)	0 to 5 V	0 V with tube supplying unmodulated rf output. 5 V with FREQUENCY Mode Selector switch in OFF position.
Grid (BWO units only)	TP10 (+) TP23 (-)	27 ±2 V (units with Stewart Tubes) 85 ±10 V (early units with Varian Tubes)* 61 ±6 V (later units with Varian Tubes)*	With controls set for RF OFF
		< 1 V	With controls set for RF ON
Injector (VTM units only)	TP21 (+) TP6 (-)		See Plug-in manual

*This supply may be field-adjusted. Follow the procedure given in Paragraph 5-3.
**See plug-in unit manual for correct value and measurement procedure.
*"early" units have Elevated Supply A12 Assembly #950620. "later" units have Elevated Supply A12 Assembly #901488 or modified 901482. See plug-in unit manual for correct voltage value.

650 supplies, then field calibration that places performance within the specifications of one rf plug-in unit should allow the other plug-in units to operate with no more than twice the specified accuracy tolerance.

A factory calibration service is available at nominal cost by returning the instrument to ALFRED. Contact your nearest representative or our sales department.

The critical adjustments and the circuits they calibrate are described below:

NOTE: Some of the adjustment methods outlined below utilize frequency-standardization techniques to determine when the correct adjustment is obtained. More accurate voltage-standardization techniques are made possible with the Model 650T Oscillator Calibration Plug-in unit, and those procedures are covered in the manual supplied with the Model 650T.

1. A1R24 BALANCE adjustment, located in the cathode supply (covered by PC board retaining plate, Figure 5-2). This adjustment is used to balance the base-emitter voltages of the input dual transistor A1Q1. These voltages do not change with age. Readjustment is required only when A1Q1 is replaced. At that time, A1R24 should be carefully set to match the base-emitter voltages on each side of the dual transistor, under actual single-frequency operating conditions with high voltage on so that closed-loop feedback is supplied.

2. A1R38 MAX CAL adjustment, located in the cathode supply (covered by PC board retaining plate, Figure 5-2). To insure complete interchangeability of all plug-in units in any Model 650, the Model 650 is calibrated against a precision "standard" Model 650T Calibration Plug-in unit at the factory. With the "standard" plug-in inserted into the Model 650, the MAX CAL is adjusted until the cathode supply output is exactly 2500 volts. This adjustment corrects for value variations in the 15 K Ω summing resistors, and the factory setting should not be changed. Readjustment is required only when a summing resistor is replaced, to bring frequency output performance (as measured with a wavemeter) within tolerance throughout the band.

3,4,5. A4R7, A4R32 and A4R55 MARKER adjustments (Figure 5-2). These adjustments are used to correct errors due to variations in the base-emitter voltage of the input transistors A4Q1, A4Q7, and A4Q13, and to compensate for any variations in the values of the summing resistors. The parameters compensated for do not change with age, and the factory adjustment should not be reset unless parts are replaced. After parts replacement, readjust only the one calibration control corresponding to the channel in which the input transistor or summing resistor has been replaced. Readjust the repaired channel so that the frequency at which its marker is generated (as measured with a wavemeter) tracks the output of the other marker channels when set to the same dial frequency. The adjustment should be set for optimum performance across the band.

6 thru 10. R71, R72, R73, R74, and R75, the calibration adjustments for the F_2, M_2, F_1, M_1, and F_0 panel controls (on "In-Voltage Calibrate" PC Board 950853 behind the front panel, Figure 5-1). These adjustments are used to electrically correct any errors due to mechanical tolerance build-up in the dial mechanism. The electrical and mechanical design of the dial mechanism offers excellent stability and realiability, and alteration of the factory-set calibration should never be required until parts replacement is required after long service. When the output frequency appears not to be calibrated to the dial settings, refer to the trouble-shooting chart, Table 5-2, to localize the source of the trouble. The dial mechanism and dial control potentiometers are the least likely cause of improper calibration, provided the factory adjustment of the mechanism itself and of these five calibration resistors has not been altered.

After replacing a particular FREQUENCY or MARKERS potentiometer or making a repair in the control mechanism for a particular dial indicator, adjust only the calibration resistor for that control. The electrical adjustment is primarily intended for calibration of the intermediate and high-band portions of the control range, after mechanical adjustments have been made on the affected channel to achieve proper calibration at the low end of the band. Adjust the calibration resistor for the repaired channel so that its single-frequency performance (as measured with a wavemeter) matches that of the other controls when set to the same dial frequency. Calibration must be checked carefully for optimum performance across the full band. If more than one dial channel must be calibrated, and/or if a Model 650T plug-in is not available to permit factory-type recalibration, it is recommended that the instrument be returned to the factory for dial calibration.

11. A9C5, TRANSFER OSC.FREQ. ADJ. (Figure 5-1). This adjustment is made at the factory and should not need further adjustment unless one of the critical components is replaced. The critical components are A9Q1, Q9Q2, A9Q3, A9L3, A9C3, A9C4, A9C5, A9C8 or A9T1. An adjustment procedure is given in Step 3. c. of Table 5-10. Failure in the transfer oscillator due to inadvertent short-circuiting of components by improper use of a metallic screwdriver will normally be limited to the demodulator and output driver circuits driven by A9T1. Replacement of components in those circuits does not require adjustment of A9C5.

5.3.3 PERIODIC RECALIBRATION ADJUSTMENTS. The following adjustments may be carefully checked and field-set to perform periodic recalibration. They should also be used for calibration after replacement of parts in the associated supplies. Because the accuracy and stability of the supply circuits in the Model 650 approach that of the best test equipment, only test equipment that has recently been calibrated should be used to check the Model 650. When the measured value falls anywhere within the tolerance range indicated, no adjustment should be performed.

1. A2R18 - 15 V ADJ. (Figure 5-2) is used to set the -15 V supply output at TP4 to -15.0000 V dc ± .0075 V dc with respect to chassis ground (TP3). When checking or making this adjustment a .01% digital voltmeter with at least five digits should be used. The digital voltmeter should have been recently calibrated. This adjustment should be checked after replacing A2Q8 or associated components shown in Figure 4-3.

2. A2R9 +15 V ADJ. (Figure 5-2) is used to set the +15 V supply output at TP2 to +15.0000 V dc ± .0075 V dc, with respect to chassis ground (TP3). Before checking or making this adjustment the -15 V supply must be checked, as the -15 V is used as the reference for the +15 V supply. A .01% digital voltmeter accurate to at least five digits should be used. This adjustment should be checked after replacing A2Q4 or associated components shown in Figure 4-4.

3. A6R21 HEATER ADJ. (Figure 5-1) is used to set the heater supply output between TP7 and TP8 to 6.3 V dc ± 0.1 V dc when the supply is loaded to 1 ampere and the input line

voltage is nominal (115 VAC). When making this adjustment the high voltage should be turned off by removing the top cover plate to trip the interlock switch. This is required for access as shown in Figure 5-1. If the interlock switch is defeated, a floating voltmeter with at least 3000 V insulation must be used. The voltmeter used should have an accuracy of at least 1%. If possible, make this adjustment while operating with a plug-in unit that draws about 1 ampere tube heater current (refer to the plug-in unit manual for details). With a plug-in unit which draws 2 amperes of current, the output should not drop below 6.1 V dc. The adjustment of A6R21 should be checked after replacing Q5, A6Q6, A6Q7, A6CR3, or associated components shown in Figure 4-9.

WARNING

When the high voltage is present, extreme caution is required. For personnel protection a non-metallic screwdriver must be used.

4. A6R5 -100 V ADJ. (Figure 5-1) is used to set the -100 V floating supply to -100 V dc ± 0.1 V dc. It should be checked after replacement of A6Q4 or A6Q5 or associated components shown in Figure 4-12.

WARNING

When making this adjustment the high voltage must be on. Extreme care should be used in the procedure. Use a non-metallic screwdriver for safety.

The following procedure permits making this adjustment without using a floating voltmeter, by making all measurements with respect to chassis ground:

a. Since the voltages to be measured are referenced to the cathode supply voltage, reduce this voltage to a minimum value by turning the FREQUENCY Mode Selector switch to SINGLE, the SINGLE Frequency Selector switch to F_0, and the F_0 FREQUENCY control to the low-frequency end of the dial.

b. Measure the voltage at the 0 LINE, at TP10, with respect to chassis ground. A 0.01% digital voltmeter capable of measuring voltages of this magnitude must be used. This voltage for some plug-in units can be as high as 2000 V. (Refer to the plug-in unit manual for applicable values.) A high-voltage probe may be used with a meter which has insufficient high-voltage capability.

c. Measure the -100 V supply output at TP11 with respect to ground, using the same meter as in Step b.

d. The voltage measured in Step c. should be -100.0 V ± 0.1 V greater than that measured in Step b. Adjust A6R5, if necessary, to achieve this output level.

5. A7R3 HELIX OVERCURRENT TRIP-OUT adjustment (Figure 5-1) is used to set the trip-out point. The basic trip-out current is 1 ma through A7R14. For other values of trip-out current, A7R14 is shunted by a resistor in the plug-in unit. Thus, the standard calibration of 1 ma through A7R14 applies to the Model 650 regardless of the plug-in unit used. This adjustment should be checked after replacement of A7Q2, A7Q3 or associated components shown in Figure 4-10.

To set the helix trip-out point, proceed as follows with the high voltage off:

a. Disconnect the wire to terminal A7-13 (on PC board A7, Figure 5-1).

b. Connect a 10 K potentiometer and 15 K ohm 1% resistor in series between terminal A7-13 and the -15 V supply (TP4). (See circuit sketch below.)

c. Adjust A7R3 so the relay A7K1 de-energizes when the potentiometer is turned to zero resistance.

d. Reconnect wire to A7-13.

NOTE: If helix overcurrent trip-out occurs, press RESET button after eliminating overcurrent condition.

6. A7R9 SWEEP AMPLITUDE adjust (Figure 5-1) is used to set the peak amplitude of the +15 V sweep voltage. This adjustment should not be attempted unless it has definitely been established that the peak amplitude of the sweep is not correct. This can be done by making two frequency measurements, and the actual adjustment should be carried out in terms of frequency performance, as follows:

a. Set the FREQUENCY Mode Selector to SINGLE, the SINGLE Frequency Selector to F_2, the F_2 FREQUENCY control to 100 on the logging scale, and the F_1 control to 0 on the logging scale. Turn the MANUAL SWEEP control to the F_2 switched position.

b. Measure the output frequency using a wavemeter.

c. Set the FREQUENCY mode selector to SWEEP ($F_1 \rightarrow F_2$). Use the .1 second calibrated sweep and set the TRIGGER switch to LINE. Leave other controls as set in Step a.

d. Measure the frequency at the end of the sweep.

e. The frequency measured in Steps b. and d. should be the same to within ± 0.5%. If not, repeat Step d. and adjust A7R9 to bring the measured frequency within the required limits.

5.4 TROUBLE SHOOTING.

5.4.1 STEPS TO FOLLOW WHEN FAILURE OCCURS. First check all voltages in accordance with Paragraph 5.2 to help localize the trouble to a supply or other circuit in the Model 650 or to the microwave tube or a circuit in the plug-in unit.

CAUTION

Do not localize the failure by putting the plug-in unit from the failed instrument into another Model 650, or by putting another plug-in unit known to be in good working condition into the failed Model 650. The reason for this is that a failure in one might cause damage to the other. The probability of such a failure occurring (where failure in one damages the other) is low, but nevertheless, precautions should be taken. Examples of such failures include a shorted plug-in unit, which would overload and damage any Model 650 into which it was placed; and failure in the heater overvoltage protection circuit of the Model 650 which would allow a tube filament to be over-driven, particularly if coupled with regulation failure in the heater supply.

Therefore, until trouble is definitely localized to one unit or the other, operate with the rf-type plug-in unit

that was installed when failure was noted. If a Power Supply Plug-in unit, Model 650-P1, is available, however, it may be installed instead of an rf-type plug-in unit for trouble shooting. The passive networks in the 650-P1 are not likely to be damaged by a defective Model 650. Do not install a Model 650T Oscillator Calibration Plug-in unit for trouble shooting, because any damage to the precision, calibrated circuits of this plug-in will render it unusable for its intended calibration purpose. The Model 650T should be installed only for calibration purposes after the trouble has been localized and corrected.

If trouble is localized to the Model 650, and particularly to the heater supply, temporarily disconnect the microwave tube connections in accordance with the diagrams given under Paragraph 5.7 to avoid applying improper voltages to the tube while operating the Model 650 to localize trouble to particular components.

After making voltage measurements, refer to the appropriate one of the trouble-shooting tables for individual supplies, if outputs are incorrect. If supplies are functioning properly, refer to the general trouble-shooting table, Figure 5-2, for assistance in locating the failed circuit and components. Before proceeding further, read the additional troubleshooting hints and cautions in the following paragraphs.

5.4.2 USE OF THE TROUBLE-SHOOTING TABLES. Tables 5-2 through 5-11 provide basic trouble shooting information for the Model 650 instrument operating with any plug-in unit. Table 5-2 is a general procedure which localizes gross performance faults to a particular circuit section. Tables 5-3 through 5-11 will be helpful to localize both failures and minor faults in individual power supplies and circuits. When the Model 650 is operating properly, these tables will localize trouble to the plug-in unit. Detailed procedures for trouble shooting circuits in the plug-in units will be found in the separate plug-in unit manuals; however, procedures for localizing trouble to the microwave tube in the plug-in unit are included in this manual.

5.4.3 VOLTAGE AND WAVEFORM MEASUREMENTS. Voltage and waveform measurements are indicated on the simplified schematics of the Model 650 circuits in Figures 4-2 through 4-16 of this manual. For each plug-in unit, simplified schematics with applicable voltage and waveform measurements are included in the plug-in unit manual. These measurements can be used for trouble shooting within the circuits referenced by the trouble shooting tables. Conditions of measurement are indicated on each schematic. Keep in mind that the voltage and waveform measurements shown are typical, intended for use in localizing trouble in faulty circuits. Even where several significant digits are shown on these "typical" measurements, they do not imply "standard" values, but instead are intended to give a better picture of the relative interstage levels in the circuit. Normal component variations can produce voltage variations commensurate with the component tolerances used in any particular circuit.

CAUTION

All measurements should be made with respect to chassis ground, unless otherwise indicated on the simplified schematics. In conjunction with measurements on the cathode supply (Figure 4-7), note that because of mechanical limitations in the dial mechanism, the instrument is factory-calibrated to produce the full frequency output range in response to a panel control potentiometer output range of approximately 0.15 V to 14.75 V. These voltages correspond to the 0-scale and full-scale dial settings. Do not attempt to change the calibration of these controls.

WARNING

All waveform and voltage measurements are made with high voltage off unless otherwise noted. Exercise extreme caution when checking high voltage circuits.

5.4.4 LOCALIZATION OF TROUBLE TO INDIVIDUAL COMPONENTS. In addition to making voltage and waveform measurements, it may be necessary to perform some active or passive circuit testing to pinpoint the defective component(s). In most cases, the performance of a particular transistor that is forward-biased can be evaluated by shorting the emitter and base lead where circuit voltages permit, or by opening the base lead. In either case, the transistor will be turned off unless it is shorted. Resultant changes in circuit voltages can be monitored to determine whether the transistor is performing. If a transistor does not conduct when its v_{be} exceeds cutoff - as can be determined by in-circuit measurements of its lead voltages (this may require base-emitter shorting or base opening on other transistors to establish proper conditions) - it can be assumed to be open.

NOTE: The tab on all single transistors identifies the emitter lead. The tab on all dual transistors identifies the collector leads.

Another method of locating open or shorted transistors is by means of resistance measurements across the elements. Because of differences in transistors and ohmmeters, no specific information can be given about exact resistances. Generally, the ratio of forward and backward emitter-collector resistance is between 10:1 and 100:1, the ratio being lower for the higher-powered transistors. When a defective transistor is located, always look for another faulty element in the circuit which may have contributed to or resulted from the transistor failure.

Resistors and capacitors should be checked with one lead unsoldered to avoid any possibility of shunt paths and/or damage to transistors and diodes. Tubes V1 through V5 are best checked by substitution. V1 through V3 in the cathode supply should be replaced together.

CAUTION

1. USE OF OHMMETER. If an ohmmeter is used to check the forward and reverse resistance of transistors, or to make in-circuit resistance measurements in transistor circuits, check the ohmmeter voltage and current output on the range to be used before making any measurements. Many ohmmeters are unsuitable for use on certain ranges because they supply enough voltage or current to damage a transistor. Check both the open-circuit voltage and the short-circuit current, using suitable test instruments. Do not use any range where open-circuit voltage exceeds 1.5 V or short-circuit current exceeds 3 ma, because these levels may damage transistors.

2. MEASURING TRANSISTOR VOLTAGES. When checking to determine whether a particular transistor is forward-biased, measure the voltage on each lead independently with respect to ground. Do not attempt to measure v_{be} in one step by attaching the voltmeter directly to both leads, because transistor-damaging auxiliary currents may be established.

3. REMOVAL OF PC BOARDS. When a PC board extender is used for convenient access to one of

the plug-in PC boards on the right-hand side of the Model 650 to allow making test measurements, or if a PC board is removed for component checking, observe the following precautions:

a. Always turn the POWER switch OFF before disconnecting or connecting any PC board, either directly to its receptacle or through the board extender. If this is not done, there is the possibility that some transistors will be burned out by transients that take place when the connection is made or broken.

b. While the board extender may be turned 180° as necessary to fit the keyed receptacles, the PC board being extended must always be kept in its normal orientation, i. e., with the components on the side toward the instrument front panel. If the PC board is inadvertently turned 180° extensive circuit damage may occur because of improper connections.

5.4.5 USE OF THEORY OF OPERATION. The detailed circuit theory given in Section 4 will be helpful in locating possible causes of trouble. A good understanding of the circuit theory will enable a technician to analyze a particular indication of trouble in terms of possible faulty circuits or components to be checked out.

Table 5-2. Trouble-Shooting Chart for the Model 650

Trouble (Indication)	Probable Cause	Remedy
1. NO PRIMARY POWER (POWER ON light does not come on when POWER switch is turned ON.) See Figure 4-2.	a. Plug-in unit safety interlock not closed.	a. Check that locking knob on plug-in unit is turned fully clockwise to actuate the safety interlock switch.
	b. Main fuse F2 blown.	b. Check the primary control circuits for a short or a faulty component. Check RT1, S1, S2, S3, K2 and K3.
	c. Low voltage fuse F1 blown (accessible from chassis bottom, Figure 5-4).	c. Check for a short on the primary side of T1. (This is best done with the L. V. supply PC board A2 removed, to reduce the load on T1. Check for shorts in the low voltage rectifier circuit wiring on the secondary side of T1 (see Schematic 900775). Check for a short on board A2. (See Figures 4-3 through 4-6.)
2. NO HIGH VOLTAGE POWER (HIGH VOLTAGE ON light does not come on after the primary power has been on for about 60 seconds.) See Figure 4-2.	a. Top or rear panel interlock switch tripped.	a. Check that top cover and silkscreened rear panel are properly installed.
	b. High voltage fuse F3 blown (accessible from chassis bottom, Figure 5-4).	b. Check the high voltage control circuit for a short or faulty component. Check S3, S5, S6 and the primary of T2. Check the cathode, anode and the -100 V supplies for shorts. See Figures 4-7, 4-8, 4-11, and 4-12.
	c. Low voltage supply failure.	c. Check the low voltage supply outputs for proper voltages. (See Paragraph 5.2 and Table 5-1. The +100 V is used to actuate high voltage control relay K2. Refer to Table 5-3 to localize trouble in any supply which has improper output.
	d. Heater overvoltage.	d. With the primary power on check to see that light A6DS2 is not on. A6DS2 is on PC board A6, Figure 5-1. If the light is on, check the heater supply adjustment (Paragroph 5.3). (Also see Table 5-6.)
	e. Helix overcurrent relay tripped (applicable to BWO plug-in units only).	e. With the primary power on check to see that relay A7K1 is energized. (A7K1 is on PC board A7 behind the front panel, Figure 5-1.) When the top cover is removed for access to A7K1, it will be necessary to manually actuate the top interlock switch to determine whether A7K1 remains energized, as it should, when high voltage is enabled. If A7K1 is not energized, check helix current as directed in Step 3. below. If the tube is drawing excessive helix current, it may have been defocused by being struck by a metallic screwdriver, and must be replaced. (See Paragraph 5.7.) See Table 5-5 below if trip-out occurs without excess current. Press the panel RESET button to restore power after the one-minute time delay, when the overload has been removed.
3. NO RF POWER OUTPUT (POWER ON and HIGH VOLTAGE ON lights are on, and no output signal is generated when controls are set for rf power output.) See Figures 4-7 thru 4-12.	a. Improper setting of panel controls.	a. Check that MODULATION and SWEEP TRIGGER controls are not set to inhibit rf output.
	b. Failure of one of the supply voltages for the microwave tube.	b. Check all supply and microwave oscillator tube voltages following the procedure of Paragraph 5.2. Refer to the appropriate table to localize trouble in any supply which has improper output.

Table 5-2. Trouble Shooting Chart for the Model 650 (continued)

Trouble (Indication)	Probable Cause	Remedy
3. NO RF POWER OUTPUT (continued)	c. Defective blanking Circuit.	c. If all tube voltages are correct except that the grid (BWO or injector (VTM) are held at the tube "off" levels, check the blanking circuit components on the sweep and modulator circuit boards. (See Tables 5-4 and 5-10.) Also check the circuit of transistor modulator A12Q1 in the plug-in unit Elevated Supply PC board. (See plug-in unit instruction manual.)
	d. Failure of the microwave tube.	d. If proper voltages are being supplied to the tube, as measured at the test points listed in Table 5-1, the trouble is in the plug-in unit, and is probably a defective microwave tube. To help localize the trouble to the tube, check the measurable electrode currents. These vary, depending upon the type of tube used. With Stewart BWO tubes, the helix and collector currents can be measured; with Varian BWO tubes, the helix current can be measured. With VTM tubes, the heater current can be measured. Refer to the plug-in unit instruction manual for the measurement procedure. If the tube is not generating output with proper voltages applied, it must be replaced. (See Paragraph 5.7.)
	e. Failure of microwave component in rf output circuit (filter, circulator, sampler, or diode solid state leveler).	e. If tube currents indicate proper operation, check the rf power output directly at the tube output connection. If no output power is supplied by the tube, replace it. If output is supplied, make progressive checks to locate the faulty component.
4. RF OUTPUT FREQUENCY WILL NOT SWEEP. (Instrument operates properly at any single frequency, but will not supply swept output.)	a. Failure of sweep circuit.	a. Check sweep generator and triggering circuits on Sweep PC board A5. (See Table 5-4.)
	b. Failure of sweep input impedance converter circuit in cathode supply.	b. Check circuit of A1Q11 and A1Q13.
5. RF OUTPUT FREQUENCY SWEEP IS NONLINEAR. (Instrument operates properly at any single frequency, but will not supply linear and/or full-band swept output.)	a. Failure of sweep circuit.	a. Check sweep generator circuit on Sweep PC board A5. (See Table 5-4.)
	b. Failure of sweep retrace discharge circuit.	b. Check V5 and other circuit components. (See Table 5-9.)
6. RF OUTPUT FREQUENCY CONTROL IS ERRATIC IN SWEPT AND SINGLE-FREQUENCY MODES.	a. Failure of low-voltage supply.	a. Check low-voltage supply outputs for proper voltages. (See Paragraph 5.2.) Refer to Table 5-3 to localize trouble in any supply which has improper output.
	b. Failure of cathode supply.	b. Check tracking of cathode supply output at TP6 against the proper values given in the plug-in unit manual, following the procedure of Paragraph 5.2. Refer to Table 5-9 below to localize trouble in the cathode supply.
7. RF POWER NOT LEVELED. (Swept output shows same variations as in unleveled condition when controls are set for leveled rf output.	a. Improper control settings.	a. Refer to Paragraph 3.12.
	b. (If external leveling is being used), insufficient output from external sampler and/or detector.	b. Measure the detector output at the frequency where minimum unleveled power is generated, using a VTVM. Switch the Model 650 to a single-frequency mode to avoid sweeping into a higher power point in the spectrum while making this check. Detector output must be at least -60 mv. If sufficient output is supplied, try turning the RF SAMPLER SENS control CCW to increase the sensitivity. CAUTION Use a non-metallic screwdriver.
	c. Defective leveler circuit component in plug-in unit.	c. Refer to plug-in unit instruction manual.

Table 5-2. Trouble Shooting Chart for the Model 650 (continued)

Trouble (Indication)	Probable Cause	Remedy
8. RF OUTPUT WILL NOT AMPLITUDE MODULATE. (Continuous, unmodulated output is supplied when controls are set for rf output and square wave modulation.) See Figure 4-16.	a. Failure of -100 V supply.	a. Check the output of this supply as directed in Paragraph 5.2.
	b. Failure of square wave modulator.	b. With an oscilloscope check input waveform to the transfer oscillator at C18 (Figure 5-1). Waveform should be a square wave with a peak-to-peak amplitude of +11 V. If improper signal is supplied, see Table 5-10.
	c. Failure of transfer oscillator. WARNING: HIGH VOLTAGE.	c. With an oscilloscope, using floating connections, check the output waveform of transfer oscillator [TP12 (+),TP11 (-)]. Waveform should be a square wave with a peak-to-peak amplitude of 5 V. If improper signal is supplied, see Table 5-11.
	d. Failure of A12Q1 modulator circuit in plug-in unit elevated supply. WARNING: HIGH VOLTAGE.	d. For BWO units check the output waveform between TP10 (+) and TP23 (-) in the plug-in unit. Use an oscilloscope with floating connections. The waveform should be a square wave with a peak-to-peak amplitude of either 25 or 75 V depending upon the tube. (Refer to plug-in unit instruction manual for details.) For VTM units check the output waveform between TP21 (+) and TP6 (-), in the plug-in unit. Use an oscilloscope with floating connections. The waveform should be a square wave with a peak-to-peak amplitude of up to 300 V. (Refer to plug-in unit instruction manual for details.)
	e. Failure of microwave tube (BWO only); grid shorted to cathode.	e. Check grid-to-cathode continuity with all power off. Replace tube if necessary.
	f. Failure of leveler.	f. Refer to plug-in unit instruction manual.
9. EXCESSIVE RESIDUAL FM. (Residual FM does not decrease when operating condition is switched from untriggered sweep to single-frequency operation.)	Failure of ac impedance converter in input of cathode supply.	Check circuit of A1Q8 and A1Q9, and also A1CR2 and A1CR3.
10. RF NOT FULLY TURNED OFF WITH FREQUENCY SWITCH IN THE OFF POSITION. (FREQUENCY Mode Selector switch is OFF; rf output is still supplied.)	Follow the localization procedure of Step 8 above. In Item b., a signal of +11 V should be obtained in the "rf off" condition. In Item c., an output of 5 V should be supplied in the "rf off" condition. In Item d., maximum grid voltage or minimum injector voltage should be obtained in the "rf off" condition.	
11. CALIBRATION CHANGES WHEN RETRACE RF IS TURNED OFF ON FAST SWEEPS. (Controls set for swept operation. Sweep is set faster than one second. RETRACE control is OFF; frequency performance as measured with a wavemeter is altered when the RETRACE switch is OFF, compared with that observed with the RETRACE switch ON.)	A small shift in calibration is customary with microwave tubes under such conditions. When using sweep times too fast for recorder readout, the RETRACE switch should be left ON unless a CRT baseline is needed.	

Table 5-3. Trouble Shooting the Low-Voltage Supplies

Trouble Indication	Suggested Cause and Remedy
1. -15 V output is 0, and +15 V output is about +2 V.	Short circuit in -50 V supply. Check -50 V supply output at TP5. If incorrect, check for a short in A2Q11, A2Q12 or associated components. If necessary remove the A2 board and check for an overload in the using circuits connected to J1-D.
2. -15 V and +15 V outputs are both 0.	a. Check wiring for defective connection to TP2 or TP4 jack, and repair as necessary. b. If TP2 shows short to ground with board A2 plugged in and no short with A2 removed, check Q3 on the main chassis for internal short or short through mounting screws to chassis.
3. Improper +15 V supply output, -15 V OK.	a. Open A2R12 (if +15 V has been shorted to ground). Check and replace as necessary. Also check Q3 on the main chassis. b. Check A2Q1 and A2R1 and replace as necessary.
4. Output of +15 V supply is about +26 V; -15 V has no line regulation.	Check Q3 on the main chassis and replace as necessary.
5. All L. V. Supply output voltages are OK except one.	Poor connection at J1. Check connection of A2 to J1, and condition of J1 socket and wiring.
6. -15 V and +15 V outputs are improper when input line voltage drops. (Regulation should be maintained to below 90 V.)	a. Check CR4, CR5, CR6, or CR7 on the main chassis for open or leaky condition. Replace as necessary.* b. Check Q1, Q3, and Q4 on the main chassis. Replace as necessary. c. Overload in decoupled +15 V line (denoted by "+15 V" on schematics). Check A9Q1, A9Q2, or A9Q3 and associated components in Transfer Oscillator PC board for short. CAUTION: High voltage should be turned off for this check. d. Check circuits using "+15 V" in Modulator PC board (see Table 5-10 and Figure 4-16).
7. Ripple in lumps on -15 V supply.	a. Check A2Q6, A2Q7, or A2Q8, and replace as necessary. b. Check Q4 on the main chassis and replace as necessary. c. Improper functioning of heater supply. Check the heater supply output between TP6 and TP7 to see that it is set at 6.3 V and is regulated. If output is improper, see Table 5-6.
8. High-frequency ripple in either 15 V supply.	a. Break in black ground lead to TP3. Check and repair as necessary. b. Oscillation in L. V. Supply PC board A2 due to defective transistor or open bypass capacitor. Locate source with oscilloscope and replace as necessary. (See Step 11.)
9. Jitter in -15 V supply (output should be stable with < 0.1 mv jitter.)	a. Check primary reference diode A2CR1 and replace as necessary. b. Check for leaky capacitor A2C7 and replace as necessary. c. Check for noisy resistor A2R17, A2R18, A2R19, or A2R24 and replace as necessary. d. Check for noisy A2Q6, A2Q7, A2Q8.
10. Jitter in +15 V supply (output should be stable with < 0.1 mv jitter.)	a. Check -15 V supply first - see Step 9 above. b. Check for noisy resistor A2R9, A2R10, A2R11, or A2R12 and replace as necessary. c. Check for noisy A2Q2, A2Q3, A2Q4.
11. Oscillation in either 15 V supply.	a. Check bypass capacitors A2C1 through A2C7 and replace as necessary. b. Check output filter capacitors C12A or C12B and replace as necessary. c. Check high frequency filter capacitor C22 and replace as necessary. (Add on units below Serial Number 301.)
12. +100 V supply output measures +145 V.	a. Case of Q1 is shorted to main chassis. Check condition and repair or replace as necessary. b. Defective transistor Q1, or socket, on main chassis. Check and replace as necessary. c. Check for short in leads of neon bulb DS3 adjacent to A1.
13. +100 V supply output only about +10 V; both 15 V supplies OK.	a. Defective transistor Q1, or socket, on main chassis. Check and replace as necessary. b. Check for open ground lead to Q1 and repair as necessary.
14. Excess ripple or poor regulation in +100 V supply.	Marginal performance from transistor Q1 on main chassis. Select and install better 2N1537 transistor in Q1 position. Check for proper performance within range of anticipated line voltage variations.
15. +100 V supply output is less than +97 V.	Marginal performance from A2Q10. Select and install 2N3638 transistor with higher β in A2Q10 position.

*In S/N 1091 & above, check corresponding components on Rectifier Assembly A15.

Table 5-4. Trouble Shooting the Sweep Generator Circuit

Trouble Indication	Suggested Cause and Remedy
1. Sweep Generator inoperative. (No sweep output, either for OUTPUT jack or swept-frequency drive.)	a. Check transistor A3Q7 and replace as necessary. b. Check transistor A3Q4 and diode A3CR4 and replace as necessary. c. Check transistor A3Q5 and replace as necessary.
2. 40 V sweep output is too low.	Excessive gain from A3Q2 circuit. Check A3Q2 and associated components. Replace as necessary.
3. 40 V sweep output is too high.	a. Marginal performance from transistor A3Q2. Select and install 2N3565 transistor with higher β. b. Check resistors A3R7 and A3R8 and diode A3CR2 and replace as necessary.
4. No sweep on fast ranges; OK on slow.	a. Marginal performance from transistor A3Q4. Select and install 2N3565 transistor with higher β. b. Check transistor A3Q2 for shorts. Replace as necessary.
5. Sweep triggers only when SWEEP TRIGGER switch is in FREE RUN position.	a. Marginal performance from transistor A3Q1. Select and install 2N3565 transistor with higher β. b. Short or other defect in A3Q2 circuit. Check A3Q2 and associated components and replace as necessary.
6. Sweep ramp waveform becomes non-linear near top.	Check transistor A3Q5 and replace as necessary.
7. Notch in sweep ramp waveform near top.	a. Check transistor A3Q5, A3Q6, or A3Q7 and replace as necessary. b. Blanking pulse pickup in lead connecting A2-E to A7-17 (units below Serial Number 111). Replace unshielded lead with shielded wire.
8. Oscillation in sweep output.	One or more defective transistors on Sweep PC board A3. Locate source with oscilloscope and replace as necessary. Check particularly transistors A3Q4 through A3Q7.
9. 40 V sweep output retraces to -15 V instead of 0 V.	Check diode A3CR7 and replace as necessary.
10. Sweep at SWEEP OUT jack is pulsed at low end instead of having linear ramp appearance.	a. Defective Cathode Supply PC board A1. Check sweep input impedance converter circuit including A1Q11 and A1Q13. Replace as necessary. b. Check transistor A7Q4 in sweep output circuit on PC board A7 and replace as necessary. c. Defective contact on F_2 potentiometer. Check F_2 potentiometer for linear performance and replace as necessary. (May require factory-type recalibration.) d. Defective Markers PC board A4. Check input circuit of A4, including summing resistors A4R30, A4R5, and A4R53.
11. 15 V sweep does not start at 0 V.	a. Defective transistor A7Q4, or socket. Check and replace as necessary. b. Transistor A7Q5 replaced by a PNP unit. Check that A7Q5 is a 2N699. c. Diode A7CR1 defective. Check and replace as required.
12. Improper sweep amplitude supplied to F_2 potentiometer from A7-23.	Check transistor A7Q5 and resistors A7R9 or A7R10, and replace as necessary.
12A. SWEEP light inoperative.	Check transistor A3Q15 and associated components, and replace as necessary.
13. Sweep signal is OK at F_2 potentiometer, but improper at OUTPUT SWEEP jack.	a. Check transistor A7Q4 and replace as necessary. b. Check resistors A7R4 and A7R5 and replace as necessary.
14. Low-voltage starting point of 15 V sweep moves up and down with adjustment of the F_1 potentiometer.	Defective connection of -15 V lead to A7-10. Check and repair as necessary.
15. Retrace pulse at A7-17 shows "double" pulse characteristic consisting of short spike at lead end.	a. Check resistors A3R33 and A3R34 for proper values. Replace as necessary. b. Check transistors A3Q12 and A3Q13 and replace as necessary.
16. Sweep time shorter than selected with SWEEP TIME control.	Check transistor A3Q4 and replace as necessary.

Table 5-4. Trouble Shooting the Sweep Generator Circuit (continued)

Trouble Indication	Suggested Cause and Remedy
17. Sweep time longer than selected with SWEEP TIME control.	a. Marginal performance from transistor A3Q2. Check 40 V sweep. If it exceeds 42 V, select and install 2N3565 transistor with higher β. b. Check A3R7, A3R8, and A3CR2 and replace as necessary. c. Check sweep time resistors R30 and R31 on front panel and replace as necessary.
18. Sweep time incorrect or erratic on 10-sec range, OK on 1-sec range.	a. Defective or marginal transistors A3Q4-A3Q7. Check and replace with higher-β units as necessary. b. Check sweep time capacitor A7C4 and replace as necessary.
19. Sweep time is 0.2 sec on 0.1-sec range, OK on 1-sec range.	Check sweep time capacitor A7C2 and replace as necessary.
20. Improper delay time between sweeps (normal delay interval is 1.7 - 2.7 ms).	a. Unsatisfactory performance from A3Q12, A3Q13, or A3Q14. Transistors with low β shorten the delay interval; transistors with high β lengthen it. Check and replace as necessary. b. Faulty capacitor A3C10. Check and replace as necessary.
21. Ripple on 50 V blanking pulse.	Defective +100 V supply. Measure +100 V output. If improper, see Table 5-3 to localize trouble.
22. 50 V blanking pulse has poor rise-time performance.	Check capacitor A3C1 and replace as necessary.
23. Sweep will not trigger from external pulse with minimum amplitude (2 V) and minimum width (10 μs).	a. Improper value of capacitor A3C4. Select and install capacitor with less capacitance to improve low-level trigger performance. CAUTION If A3C4 is reduced to too low a value, the circuit will become self-triggering on the 10-sec. sweep position. b. Marginal performance from transistors A3Q8, A3Q9 and A3Q10. Select and install transistors with higher β.
24. Sweep is self-triggering on 10-sec position with the SWEEP TRIGGER control in the MANUAL or EXTERNAL position.	a. Improper value of capacitor A3C4. Select and install capacitor with a value of 24 pf or greater. Do not use too high a value (see Step 23 above). b. Excessive gain from transistors A3Q8, A3Q9, and A3Q10. Select and install transistors with lower β.

Table 5-5. Trouble Shooting the Helix Overcurrent Protection Circuit and Collector Current Monitoring Circuit

Trouble Indication	Suggested Cause and Remedy
1. Voltage drop across shunt resistor A7R14 is incorrect.	Defective helix shunt resistors A12R2 (in plug-in unit) or A7R14. Check and replace as necessary. (See plug-in unit manual for correct value of A12R2.)
2. Helix overcurrent trip-out occurs erratically.	a. Check transistors A7Q1, A7Q2, or A7Q3 and replace as necessary. b. Defective or magnetized relay A7K1. Check and replace as necessary.
3. Helix overcurrent relay energizes properly when power is turned on, but subsequently de-energizes.	a. Check transistors A7Q1, A7Q2, or A7Q3 and replace as necessary. b. Check for open resistor A12R2 in plug-in unit and replace as necessary. (See plug-in unit manual for correct value of A12R2.)
4. Helix overcurrent relay does not trip when overload occurs.	a. Check transistor A7Q1 for shorted condition and replace as necessary. b. Improper value of resistor A12R2 in plug-in unit for the desired trip-out current. (See plug-in unit manual for correct value.)
5. Collector current-monitoring voltage drop measured between TP21 and TP1 (some BWO plug-in units only) is outside the specified range.	Defective collector monitoring resistor A12R13 in plug-in unit. Check and replace as necessary.

Table 5-6. Trouble Shooting the Heater Supply and Heater Overvoltage Protection Circuits

Trouble Indication	Suggested Cause and Remedy
1. Voltage output is very low (1 - 2 V).	a. Defective transistors A6Q6 or A6Q7 or Zener diode A6CR10 in Heater Supply PC board A6, or Q5 on main chassis. Check and replace as necessary. b. Half-open secondary winding between terminals 15-16-17 of low voltage transformer T1. Check voltage developed across each half of the winding. Replace T1 if necessary. c. Check rectifier diodes CR17 and CR18 and replace as necessary.*
2. Excessive ripple or poor regulation of 6.3 V dc output.	a. Check zener diode A6CR3 and replace as necessary. b. Check transistors A6Q6 and A6Q7 and replace as necessary.
3. Heater overvoltage protection circuit does not trip out when overvoltage occurs.	a. Check transistor A6Q8 and diodes A6CR4 or A6CR5 and replace as necessary. b. Check relay A6K1 and replace as necessary.

Table 5-7. Trouble Shooting the -100 Volt Supply

Trouble Indication	Suggested Cause and Remedy
1. Supply cannot be set to -100 V; output is about -120 V.	Check transistor A6Q1 and replace as necessary.
2. Excessive ripple or poor regulation in supply output.	a. Check transistors A6Q2-A6Q5 and diode A6CR2 and replace as necessary. b. Check rectifier diodes CR13-CR16 on the main chassis and replace as necessary.*

Table 5-8. Trouble Shooting the Anode Supply

Trouble Indication	Suggested Cause and Remedy
1. Supply loses regulation when operated with plug-in unit which has control feedback set for an output voltage near either supply limit (+30 V or +300 V).	a. Check tube V4 by substitution, and replace if necessary. b. Check rectifier diodes CR9-CR12 on the main chassis and replace as necessary.*
2. Supply Oscillates.	a. Check resistor R76 and capacitor C20 on V4 socket and replace as necessary. b. Excessive gain in circuit of A6Q10 and A6Q11. Check circuit components. If necessary select and install 2N3565 transistors with lower β.
3. Supply loses regulation with small drop in line voltage (e. g. to 103 V).	Poor regulation performance of -100 V supply. See Table 5-7.

Table 5-9. Trouble Shooting the Cathode Supply

Trouble Indication	Suggested Cause and Remedy
1. Poor regulation in supply output with variations in line voltage.	a. Defective regulator tubes V1, V2, or V3. Check by substitution and replace all three tubes as a group if replacement is necessary. b. Check +100 V supply regulator transistor Q1 on the main chassis, and replace as necessary. c. Marginal performance from transistors A1Q2, A1Q3, A1Q4 and A1Q5. Select and install 2N3646 transistors with higher β. CAUTION Excessive β will produce ringing in response to pulsed load on cathode supply.
2. Erratic output voltage from cathode supply.	a. Check dual transistor A1Q1 and replace as necessary. (May require factory-type recalibration.) b. Check for open transistor A1Q2 and replace as necessary. c. Sweep retrace discharge tube V5 arcing. Check by substitution, and replace as necessary. d. High-voltage pickup through insulation breakdown in photocell unit A6V1. Check by temporarily disconnecting low-voltage leads from the top of A6V1. Replace if necessary.
3. Supply output ripple is the same when the FREQUENCY switch is in the SINGLE position as when it is in a SWEEP position (should reduce by about 4:1 in the SINGLE position).	a. Check transistors A1Q8 and A1Q9 and replace as necessary. b. Check capacitor A1C11 and replace as necessary.

*In S/N 1091 & above, check corresponding components on Rectifier Assembly A15.

Table 5-9. Trouble Shooting the Cathode Supply (continued)

Trouble Indication	Suggested Cause and Remedy
4. Supply output voltage does not follow the curve presecribed.	Defective diode shaper board in plug-in unit. Refer to plug-in unit manual for checkout procedure.
5. The supply output voltage set with the F_2 potentiometer in single-frequency mode is different from the voltage set with any other control turned to the same dial frequency (MANUAL SWEEP control must be fully CW).	a. Check transistors A1Q10, A1Q11, A1Q12, or A1Q13 and replace as necessary. b. Check capacitors A1C1 or A1C2 and replace as necessary. c. Check summing resistor circuits in the Markers PC board A4. d. Resistors A1R3 or A1R4 out of tolerance. Check and replace as necessary.* e. Defective frequency control potentiometer, malfunctioning dial mechanism, or improperly adjusted calibration resistors. Return the instrument to the factory for recalibration or use the 650T plug-in unit and follow the prescribed calibration procedures.

*May require factory-type recalibration.

Table 5-10. Trouble Shooting the Modulator and Transfer Oscillator

Trouble Indication	Suggested Cause and Remedy
1. No grid voltage output at TP23 (BWO plug-in units) when the FREQUENCY Mode Selector is turned OFF (Should be -25 V or -75 V) or Positive INJECTOR voltage output as prescribed for the "rf on" condition is supplied at TP21 (VTM plug-in units) when the FREQUENCY Mode Selector is turned OFF (should be 0 V).	a. Improper output voltage from -100 V supply. Check output voltage between TP10 and TP11 using an oscilloscope with floating connections. If output is incorrect, see Table 5-7. WARNING This is a high voltage measurement. Set the output frequency to the low end of the band to reduce the reference level of the "0 line." b. Defective Modulator PC board A5. Check output waveform at C18 (Figure 5-1). Level should be 0 V for rf full on; about +11 V for rf off. If modulator output is OK, the fault is in the Transfer Oscillator PC board A9 or in the plug-in unit. If modulator output is incorrect, check that the proper blanking input of about +2 V is being supplied to A5-W by the Sweep PC board A3. Clear any fault in A3 by referring to Table 5-4. Then check the circuits of A5Q8, A5Q3, and A5Q5 in the modulator. Replace components as necessary. c. Defective Transfer Oscillator PC board A9 (if waveform check at C18 shows the proper signal is being supplied from the modulator). Check output waveform between TP12 and TP11 using an oscilloscope with floating connections. TP12 should be +5 V with respect to TP11 for rf off and 0 V for rf on. If this output is correct, the fault is in the plug-in unit, in the circuit of A12Q1. If transfer oscillator output is incorrect, check components in A9. WARNING Check components with high voltage off. d. Defective A9 demodulator driver stages. Check A9CR3, A9CR4, A9Q4 and A9CR5 and associated components. e. Defective rf oscillator stage. Check for oscillator output at the junction of A9C4 and A9C6. If components are replaced, adjust the oscillator frequency to obtain optimum demodulated power following the procedure of Step 3 b. below. f. Defective oscillator amplifier/modulator. Check A9Q2, A9Q3, A9CR2, A9CR1 and associated components, particularly coupling capacitors.
2. GRID voltage output at TP23 (BWO plug-in units) remains at -25 V or -75 V when the FREQUENCY Mode Selector is turned to SINGLE; or INJECTOR voltage output at TP21 (VTM plug-in units) remains 0 when the FREQUENCY Mode Selector is turned to SINGLE (should be prescribed positive value).	a. Localize the trouble to the Modulator or Transfer Oscillator PC boards or the plug-in unit by making the measurements of b. and c. in Step 1 above. b. Defective component in modulator output stages. Check A5Q3 or A5Q5 and associated components. c. Defective component in transfer oscillator. See Steps d., e., and f. of Step 1 above.
3. Low GRID output voltage at TP23 (BWO plug-in units); or INJECTOR output voltage at TP21 (VTM plug-in units) is not close enough to zero when controls are set as in Step 1 above.	a. Improper output voltage from -100 V supply. See Step 1 a. above. b. Diode A9CR5 shorted. Check and replace as necessary. c. Transfer oscillator output improperly adjusted. Check transfer oscillator output waveform as directed in Step 1 c. above, using fast-rise oscilloscope and operating the Model 650 in square wave mode. Note the position of the adjustment screw of TRANSFER OSC FREQ ADJ A9C5. Then carefully make a slight trial adjustment in each direction to see if the rise time of the transfer oscillator output waveform can be improved. A9C5 should be set to the

Table 5-10. Trouble Shooting the Modulator and Transfer Oscillator (continued)

Trouble Indication	Suggested Cause and Remedy
3. (continued)	position that gives the fastest rise time in the transfer oscillator output waveform. The rise time should be about 0.1 μs. If output waveform has an amplitude of less than 5 V, check the transfer oscillator components as in Steps 1-d. through f. above, and replace as necessary. d. Defective modulator circuit in plug-in unit. Check A12Q1 and associated components (see plug-in unit manual).
4. Excess ripple in GRID output voltage at TP23 (BWO plug-in units) or INJECTOR output voltage at TP21 (VTM plug-in units).	a. Poor regulation in low or high-voltage supplies. Check supplies for ripple and refer to the appropriate table to localize trouble. b. Marginal performance from transistor A9Q1. Check A9Q1 by substitution. (Excess ripple may be produced with satisfactory output level.) If A9Q1 is replaced, adjust A9C5 for best rise time as directed in Step 3 c. above. c. Oscillation or ripple pickup from modulator or leveler. Check signal inputs to transfer oscillator at A9-3 and A9-4 (C18 and C19) for excess ripple. If found, localize the source by circuit tracing with an oscilloscope.
5. Retrace blanking cannot be obtained; rf output is properly turned off when FREQUENCY switch is OFF. (Otherwise, see Step 1 above.)	a. Improper blanking signal supplied by Sweep PC board A3. Check blanking signal supplied to A5-W, using an oscilloscope, while operating the Model 650 in a sweep mode. The signal should be a rectangular pulse with an amplitude of about +12 V during the sweep and +2 V during retrace. If an improper signal is being supplied, refer to Table 5-4 to localize trouble. b. Defective switch(s) or wiring between A5-X and ground. Check circuits of S12, S13, and S14. (See Figures 4-16, 4-17, and 4-18.)
6. Internal square-wave modulation is inoperative; EXT AM and blanking OK.	a. Defective component is 2 Kc oscillator circuit. Check waveform at junction of A5R4 and A5C2 using an oscilloscope. If no output is generated, check A5Q1, A5C1, and R36, and replace as necessary. b. Defective gate or multivibrator input stage. Check A5Q2 and A5Q4 and associated components. Replace as necessary.

Table 5-11. Trouble Shooting the Marker Generator

Trouble Indication	Suggested Cause and Remedy
1. No Markers	a. Defective transistors A4Q2, A4Q3, A4Q8, A4Q9, A4Q14, A4Q15, or A4Q19, caused by connecting A4 board with power on. Check and replace as necessary. b. Defective resistor in amplitude selection circuit. Check A4R73, A4R74, A4R75, A4R77 and replace as necessary.
2. Markers do not have identical amplitude.	Marginal performance from A4Q6, A4Q12, or A4Q18. Check the transistor in the circuit producing the lowest amplitude marker and replace it with a 2N 3638 transistor having higher β if necessary.
3. One or more markers do not appear at the selected frequency.	Defective input transistor A4Q1, A4Q7, or A4Q13 in the malfunctioning circuit. Check and replace as necessary.*
4. Oscillation in markers circuit.	Improper value of A4C2, A4C4, or A4C6. Locate the circuit producing the oscillations by using an oscilloscope. Check the capacitor in that circuit and adjust its value by replacement or padding as necessary to eliminate oscillations.

*May require factory-type recalibration.

5.5 ALIGNMENT OF PLUG-IN UNIT.

(Refer to plug-in unit manual for field adjustments.)

5.6 REPLACEMENT OF FREQUENCY AND MARKER POTENTIOMETERS.

CAUTION

If any of the frequency or marker potentiometers are replaced in the field, the instrument must be recalibrated at the factory unless a Model 650T Sweep Oscillator Calibration Plug-in unit is available to permit accurate calibration in the field. The unit can be operated without calibration, but frequency specifications will not be met.

NOTE: The F_1 and F_2 potentiometers can be removed without dropping the front panel. Removal of the M_1, M_2 or F_0 potentiometers requires dropping the front panel forward for access. (See Paragraph 5.6.1 for the procedure.)

5.6.1 REMOVAL OF FRONT PANEL. To remove the front panel and tilt it forward from the chassis for access to the dial mechanism, proceed as follows:

a. Remove the top cover by removing its nine attaching screws.

b. Remove the right and left handle sides by removing the four corner screws.

c. Remove the five FREQUENCY and MARKERS control knobs.

d. Remove the panel dial mechanism cover by removing the Phillips screw from each end.

e. Remove the plate which retains the coiled cable and TB901 from the right side of the chassis by removing two Phillips screws which attach the plate.

f. Release the front panel from the chassis by removing the three Phillips screws from each side and the two Phillips screws from the bottom.

g. Carefully tilt the top of the front panel outward while keeping the bottom edge close to the chassis as required by the wiring harnesses. Rest the plate removed in Step e. above at a convenient point to avoid damage to the TB901 wiring.

5.6.2 REPLACEMENT OF F_1 POTENTIOMETER.

Proceed as follows:

a. Remove top cover.

b. Unsolder leads from potentiometer terminals.

c. Rotate F_1 control knob full counterclockwise (CCW) to its lower mechanical stop. It is important to remember the exact position of the indicator when the stop is reached, as this position must be maintained when the new potentiometer is installed.

d. Loosen both potentiometer shaft gear hub set screws.

CAUTION

Do not disrupt relative position of the F_2 potentiometer shaft gears. Make a pencil mark on the mounting plate and gear and realign before meshing the F_1 gear. If the F_2 gears are moved and not realigned, the mechanical stops will not be oriented and realignment must be performed according to the procedures of Paragraph 5.6.3, starting with Step h.

e. Slide gear forward.

f. Remove potentiometer retaining nut and washer. While holding nut, washer and gear, withdraw potentiometer from mounting plate, noting orientation of potentiometer terminals.

g. Insert new potentiometer engaging washer, nut and gear. Tighten retaining nut, remembering orientation of potentiometer terminals.

h. Position the F_1 potentiometer shaft full clockwise (CW) as viewed from the shaft end. This can best be accomplished by lightly tightening one gear set screw and while the gear is disengaged, finger turning the shaft full clockwise. Loosen the set screw.

i. Before engaging the gear, check to see if the dial indicator is in the exact position as it was before and check to see if the F_2 gear lines up with its pencil mark.

j. Engage the F_1 potentiometer shaft gear and tighten both screws.

NOTE: If the indicator is not in the exact position as noted in Step c., do not position it by turning the F_1 dial cord drum. Instead, disengage the gear and reposition the indicator.

5.6.3 REPLACEMENT OF F_2 POTENTIOMETER.

a. Remove the top cover, the five control knobs, and the dial mechanism cover.

b. Unsolder the three leads from the potentiometer terminals. Remove the three small screws which hold the coiled wire bracket to the back of the potentiometer. The coiled wire is now free.

c. Rotate F_1 knob full counterclockwise (CCW) and the F_2 knob full clockwise (CW).

d. Loosen F_2 potentiometer gear hub set screws on both gear hubs.

e. Remove F_2 potentiometer by turning the potentiometer case in a clockwise direction as viewed from the shaft end.

f. Insert new potentiometer and tighten by turning in a counterclockwise direction.

g. Tighten set screws on gear hub closest to the mounting plate.

h. Disengage the idler gear connecting the F_1 potentiometer shaft gear to the F_2 potentiometer body gear.

i. Set the upper mechanical stop. This stop can be seen as a bent tooth on the gear on the F_2 potentiometer shaft and a small extension on the F_2 dial indicator shaft gear. The stop must be set below the center line of the F_2 dial indicator gear and the F_2 potentiometer gear as the F_2 knob turns clockwise.

It may take a few attempts but no difficulty should be encountered.

j. Tighten the potentiometer shaft gear set screws.

k. Rotate the F_2 knob counterclockwise until the F_2 indicator is approximately 1/64" from the F_1 indicator. Now, while holding the F_2 knob so as to maintain the 1/64" distance, rotate the entire F_2 potentiometer counterclockwise (CCW) until the mechanical stop is felt. If the indicators touch because the F_2 knob was allowed to turn after the stop was reached, a slight clockwise turn on the F_2 knob will separate them.

l. Very carefully engage the idler gear between the F_1 potentiometer shaft gear and the F_2 potentiometer body gear (the one closest to the mounting plate) and tighten set screws.

The lower and upper mechanical stops are now set. A gap should be maintained between indicators over the entire distance of the dial. Adjustments should be made beginning with Step h. if gap is not maintained.

m. After the stops have been set, run the F_2 indicator full clockwise (CW) and the F_1 indicator to approximately 50 on the logging scale.

n. Remove the three screws from the back of the F_2 potentiometer.

CAUTION

Do not let the back of the potentiometer come off.

o. Secure the coiled wire bracket to the back of the potentiometer, and solder the three leads to the potentiometer terminals.

5.6.4 REPLACEMENT OF M_2 POTENTIOMETER.

a. Unsolder the wires to potentiometer terminals.

b. Turn the M_1 and M_2 knobs full counterclockwise (CCW).

c. Remove retaining ring and thrust washer from the M_2 knob shaft.

d. Loosen the two set screws on the M_2 knob shaft gear hub.

e. Loosen the M_2 dial cord hub and press M_2 knob shaft about halfway out.

f. Loosen potentiometer shaft gear hub set screws.

g. Remove potentiometer retaining nut and washer and remove M_2 potentiometer remembering orientation of potentiometer terminals.

h. Position idler gear (with planetary gear) and new potentiometer shaft full clockwise (CW) as viewed from the front panel.

i. Insert new potentiometer and tighten retaining nut remembering potentiometer orientation.

j. Engage potentiometer shaft gear and tighten set screws. Make sure the potentiometer shaft is full clockwise (CW).

k. Press M_2 knob shaft into place and replace thrust washer and retaining ring.

l. Engage M_2 knob shaft gear with idler gear and potentiometer shaft gear.

m. Tighten set screws on M_2 knob shaft gear.

n. Rotate M_2 knob fully counterclockwise (CCW).

o. Rotate M_2 dial cord CCW until dial indicators are approximately 1/64" apart.

p. Tighten M_2 dial cord drum set screw.

5.6.5 REPLACEMENT OF THE M_1 POTENTIOMETER.

a. Remove the Helix Overcurrent PC board A7, and the "In Voltage Calibrate" PC board assembly 950853. This will permit a wrench to be inserted from the left side of the gear assembly as viewed from the front of the unit.

b. Position M_1 and M_2 control knobs full CCW. Note position of indicators.

c. Loosen the M_1 potentiometer shaft gear hub set screws.

d. Remove M_1 potentiometer retaining nut and withdraw M_1 potentiometer, remembering orientation of potentiometer terminals.

e. Insert new potentiometer. Tighten retaining nut.

f. Replace M_1 potentiometer shaft gear making sure that the M_1 indicator is in previous position and the M_1 potentiometer shaft is full clockwise (CW).

g. Tighten set screws on potentiometer shaft gear.

h. Replace Helix Overcurrent PC board and assembly 950853.

i. Resolder leads.

5.6.6 REPLACEMENT OF THE F_0 POTENTIOMETER.

a. Rotate the F_1, F_0, and F_2 control knobs full counterclockwise (CCW).

b. Unsolder the leads to the F_0 potentiometer terminals.

c. Remove the F_1 knob shaft retaining ring and thrust washer.

d. Loosen the F_1 dial cord drum set screws, remembering the exact position of F_1 indicator.

e. Move F_1 knob shaft forward disengaging F_1 knob shaft gear. Loosen F_1 knob shaft gear hub set screws.

f. Slide F_1 knob shaft forward until inner locking ring bottoms on F_1 knob shaft gear.

g. Loosen set screws on F_0 potentiometer shaft gear.

h. Loosen potentiometer retaining nut.

i. Withdraw potentiometer remembering orientation of potentiometer terminals.

j. Insert new potentiometer positioning shaft full clockwise (CW) as viewed from the shaft end.

k. Tighten potentiometer retaining nut.

l. Engage F_0 potentiometer shaft gear and tighten two set screws.

m. Loosen set screw on F_0 dial cord drum and note position of indicator. Rotate F_0 knob full counterclockwise (CCW). The stop of the potentiometer should be felt.

n. Position the F_0 indicator to position as noted in step m.

o. Tighten F_0 dial cord drum set screw.

p. Replace F_1 knob shaft into position and replace thrust washer and retaining ring.

q. With the F_1 potentiometer shaft fully clockwise (CW), slide the F_1 knob shaft gear up and intermesh with F_1 potentiometer shaft gear. Tighten gear set screws.

r. Rotate F_1 knob shaft fully counterclockwise (CCW) and tighten F_1 dial cord drum after positioning indicator as it was before, step d. above.

s. Resolder leads.

5.7 REPLACING THE MICROWAVE TUBE.

5.7.1 GENERAL. The microwave tube is located in the Oscillator Plug-in unit, as shown in Figure 2-1. (See the plug-in unit manual for additional illustrations.) The elapsed time indicating meter is visible in the back section of the plug-in unit when the dial plate storage compartment door is lifted. Because tubes from different manufacturers are used in the Model 650 Series, different installation procedures are required, as given in Paragraphs 5.7.2 through 5.7.4. After replacing a tube, follow the procedure of Paragraph 5.7.5 to reset supply voltages as required by the new tube before turning power on. Refer to the plug-in unit manual for information on tube ageing and warranty replacement procedures.

CAUTION

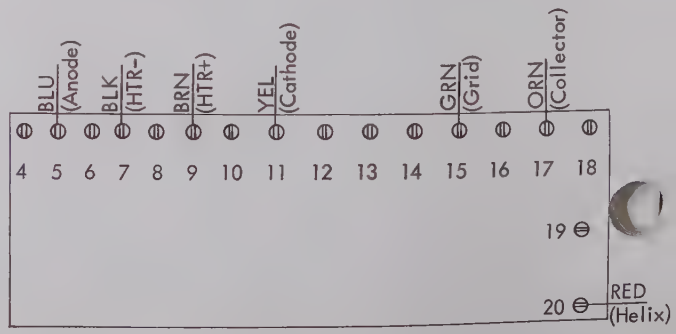
Use non-ferrous tools when removing and installing microwave tube.

5.7.2 UNITS WITH WATKINS-JOHNSON (STEWART) BWO TUBES.

a. With the plug-in unit removed from the Model 650, remove the plug-in top and bottom cover plates.

b. Remove the four (4) mounting screws which hold the tube to the mounting plate. This plate can be seen from the bottom of the unit.

c. Unsolder the tube leads at the Elevated Supply PC board (A12). The diagram below locates the terminals used on the elevated supply PC board.



d. Disconnect the instrument rf line from the tube rf output connection. On units with baluns, also remove the balun from its mounting plate by removing the attaching screws. Do not detach the balun from its connecting wires to the tube housing. The balun furnished with the replacement tube must be installed with that tube, and the old balun remains a part of the tube removed.

e. Install the replacement tube by the reverse of the above procedure.

f. Check tube voltages in accordance with Paragraph 5.7.5.

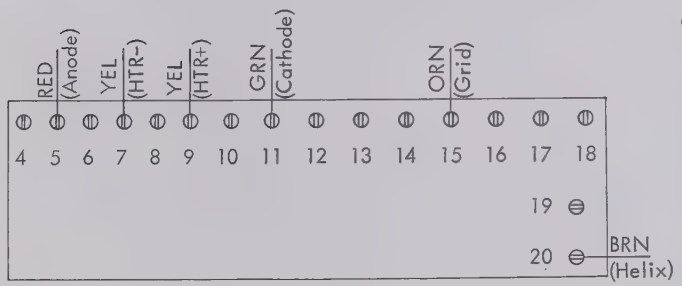
g. Replace the elapsed time meter M1.

5.7.3 UNITS WITH VARIAN BWO TUBES.

a. With the plug-in unit removed from the Model 650, remove the plug-in top and bottom cover plates.

b. Remove the six (6) mounting screws which hold the tube to the side of the unit.

c. Unsolder the tube leads at the Elevated Supply PC board (A12). The diagram below locates the terminals used on the elevated supply PC board.



Black to ground. (Ground post located toward rear of plug-in unit.)

CAUTION: The BLUE lead from the BWO tube must be connected to the ground lug located behind the time meter. If this lead is broken or disconnected, tube damage may occur. The ground connection of the tube exterior through the mounting hardware and/or the shell of the rf output connection line does not provide the internal ground reference required for proper operation. The proper internal ground is provided ONLY when the BLUE lead is properly connected to chassis ground. The tube must never be operated without this ground connection.

d. Disconnect the instrument rf line from the tube rf output connection.

e. Install the replacement tube by the reverse of the above procedure.

f. Check tube voltages in accordance with Paragraph 5.7.5.

g. Replace the elapsed time meter M1.

5.7.4 UNITS WITH MAGNETRON TUBES.

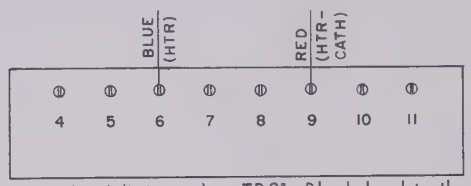
CAUTION

These tubes are very sensitive to magnetic materials. Always use non-ferrous tools when performing maintenance on them. Do not jar them or allow a tool to strike them, as the magnetic field may be disrupted. This may cause permanent damage. Always rest the tube on sponge rubber until it is installed in the plug-in unit.

a. With the plug-in unit removed from the Model 650, remove the plug-in top cover plate.

b. Disconnect the rf output coax line from the VTM tube.

c. Unsolder the filament, cathode, and ground leads at the elevated supply PC board (A12). The diagram below locates the terminals used on the elevated supply PC board. Unsolder the injector lead from its connection to TP21, the INJECTOR test point.



White lead (injector) to TP21. Black lead to the ground lug located behind the time meter.

d. Remove the nuts from the two (2) screws which retain the tube to the front chassis cross-member of the plug-in unit. Remove the tube.

NOTE: Before attaching the new magnetron tube to the plate, apply a coating of silicon grease between the plate and the tube. This provides improved heat transfer.

e. Install the new tube by the reverse of the above procedure.

f. Replace the elapsed time meter M1.

5.7.5 ADJUSTMENT OF POWER SUPPLY VOLTAGES FOR THE REPLACEMENT TUBE.

a. Before turning power on, determine whether the anode supply feedback resistor A12R14 in the plug-in unit must be changed. To do this, compare the anode (or injector) voltage requirement listed on the specification sheet shipped with the tube with the tabulation of supply output voltages versus feedback resistor values given in Figure 5-8. If the indicated feedback resistor value does not agree with the resistor installed in the plug-in unit on Elevated Supply PC board A12, install a replacement resistor of the correct value.

b. Turn power on and check all supply and tube voltages in accordance with Paragraph 5.2 and Table 5.1.

c. Adjust the anode voltage to the specified value by turning the ANODE ADJ. control with a non-metallic screwdriver. This control has a limited range, and if it is necessary to increase anode voltage above the specified value to obtain rated power output, the value of A12R14 may have to be increased. (See Par. 5.3.5 of the plug-in unit manual to check output power.)

d. NOTE: Always retain the manufacturer's data sheet for the new tube for future reference, by placing it in the envelope at the rear of this manual. Discard the data sheet for the old tube to avoid confusion.

5.8 REPLACEMENT OF OTHER COMPONENTS AND CONTROLS.

5.8.1 REPLACEMENT OF FRONT PANEL SWITCHES. To replace multi-section switches, refer to the wiring diagrams given in Figures 4-17 and 4-18. For all other switches and potentiometer controls, refer to the overall schematic diagram 900775 in Section 7. As you disconnect each wire from the defective switch or control, note its wire color on the diagram to simplify resoldering each wire to the proper terminal on the new switch. If there is any question as to the correctness of the new installation, check by circuit-tracing in accordance with the schematic or wiring diagrams before power is applied.

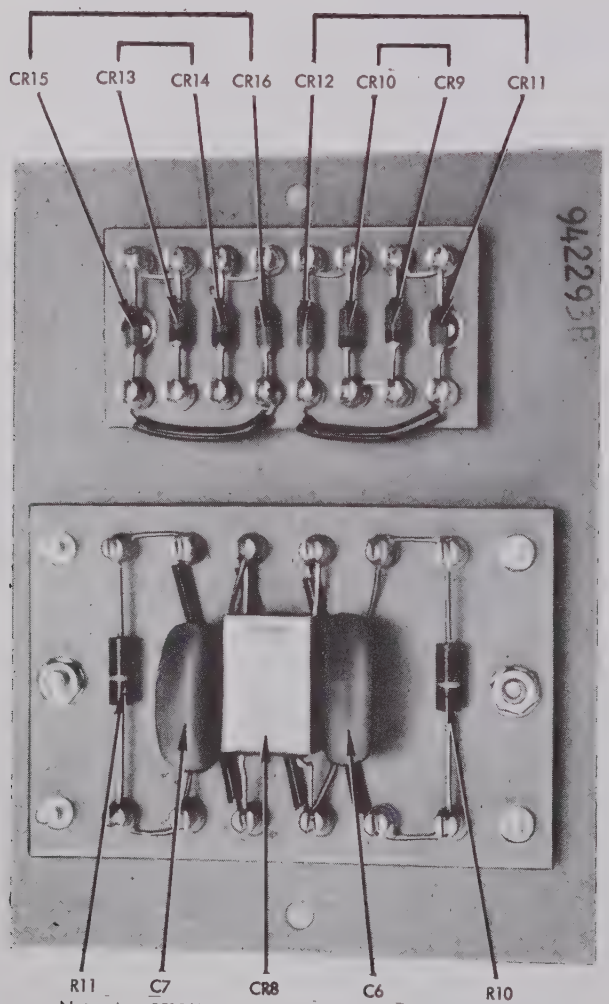
5.8.2 REPLACEMENT OF PARTS ON PRINTED CIRCUIT BOARDS. Parts on all PC boards are identified by silkscreened reference designators. They are shown on both the simplified schematics (Figure 4-2 through 4-16) and the overall schematics in Section 7. To remove individual components from PC boards, first make a diagram showing the exact orientation and connection of the part to simplify future installation. Use a low-power soldering iron (50 watts maximum) and apply heat sparingly to the lead of the part to be replaced. (The simplest way to remove a transistor is to cut its leads, and then unsolder the ends of the leads that are left in the board.) When removing the device leads, use a toothpick or a small awl to clear the holes of softened solder. Avoid excessive heat, and always ground the soldering iron to prevent leakage voltage from damaging the component.

When connecting the replacement component, trim the leads so they will penetrate the board abour 1/16 inch with the component positioned about 3/16 inch above the board. Hold the part on the component side, and solder the leads from the other side. If possible, hold the component lead on the component side with a tool which will act as a heat sink, such as a pair of needle-nose pliers. Solder with the absolute minimum of heat necessary to completely melt the solder, to avoid overheating. Use a high-quality rosin core solder only; never use paste flux. After soldering, trim off excess leads and flux.

If a break occurs in the etched copper circuit, repair it by soldering a short length of tinned copper wire across the break. Copper that lifts off the board should be cemented in place with a quick-drying acetate base cement having good electrical insulating properties.

5.8.3 REPLACEMENT OF CHASSIS-MOUNTED PARTS. Most parts mounted directly on the chassis or on terminal boards are identified by silkscreened reference designators. Parts not so identified are called out in Figures 5-1 through 5-7 for easy reference. These parts are all shown on the overall schematic diagram, 900775, in Section 7, and most of them also appear on the applicable simplified schematic diagrams in Section 4. For soldering work, a 50-watt iron and high-quality rosin core solder should be used. Avoid overheating, and use a pair of needle-nose pliers as a heat sink on the component end of the lead as an extra precaution.

5.8.4 ADJUSTMENTS REQUIRED AFTER PARTS REPLACEMENT. Refer to Paragraph 5.3 for adjustments required after replacement of parts.



Note: Assy 951061 used in S/N 1091 & up has all components identified by silkscreened reference designators.

FIGURE 5-5. DETAIL VIEW OF HIGH VOLTAGE RECTIFIER CIRCUIT BOARD (S/N 1090 & below)

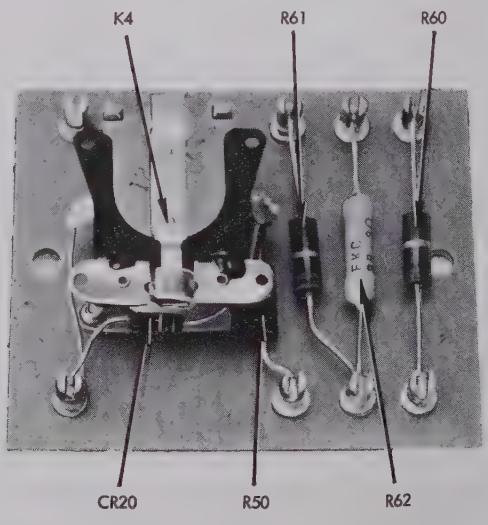
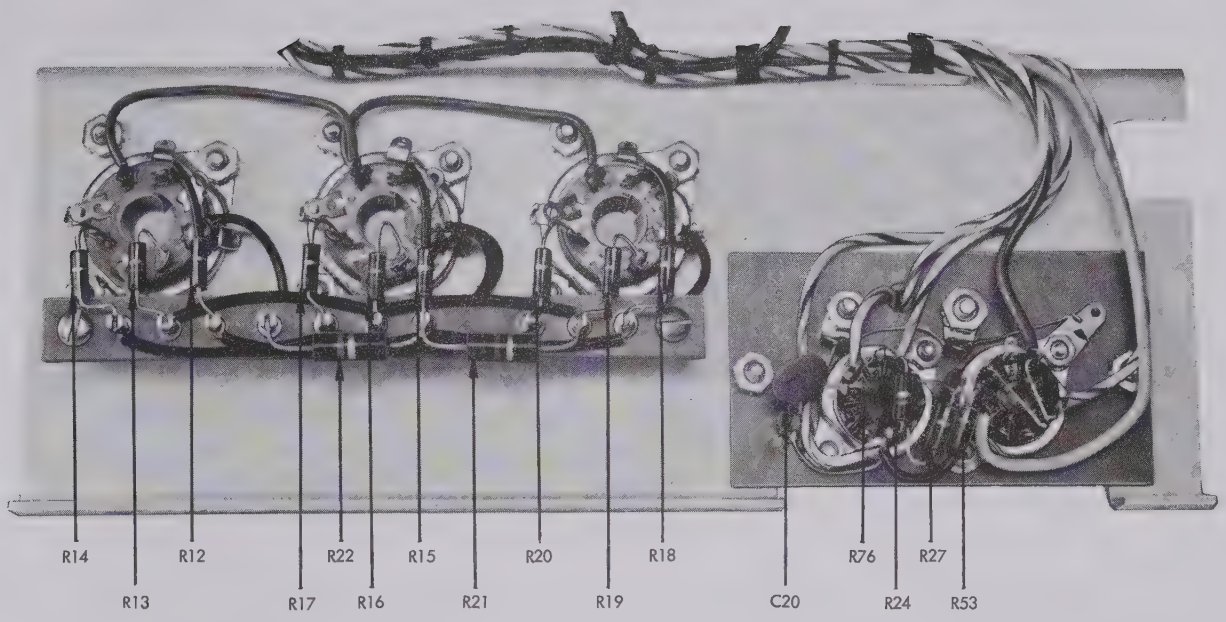


FIGURE 5-6. DETAIL VIEW OF AUXILIARY SIGNAL CIRCUIT BOARD



Note: Assy 951083 used in S/N 1051 & up has all components identified by silkscreened reference designators.

FIGURE 5-7. DETAIL VIEW OF HIGH VOLTAGE TUBE SUBCHASSIS (S/N 1050 & below)

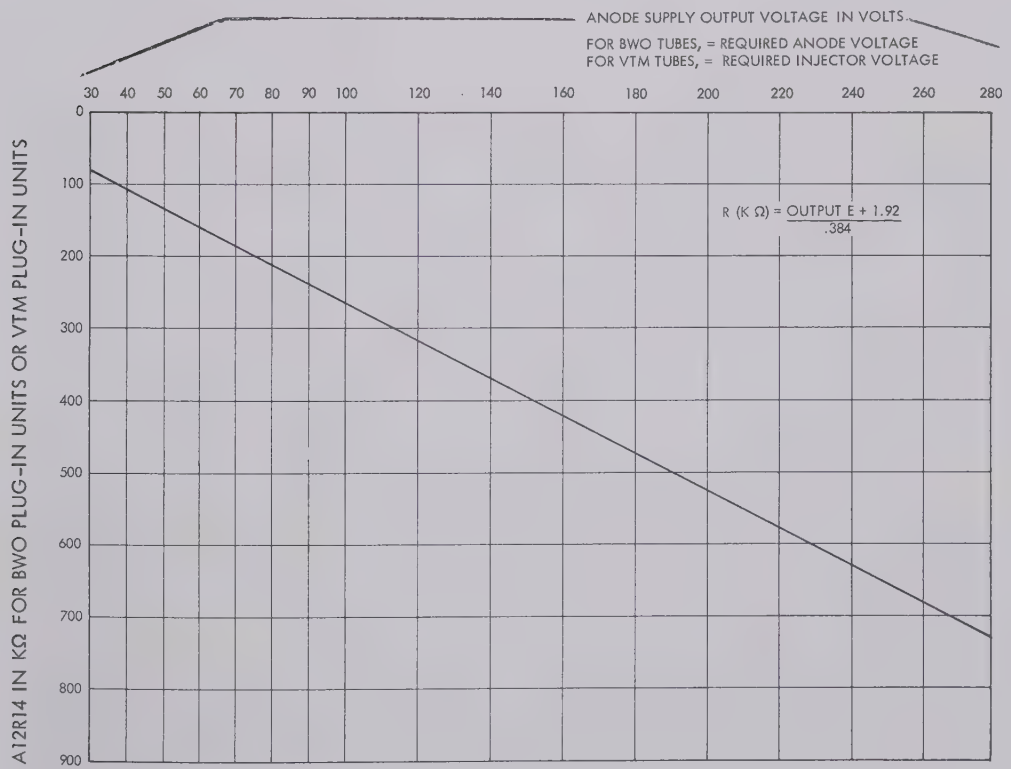

ANODE SUPPLY OUTPUT VOLTAGE IN VOLTS
FOR BWO TUBES, = REQUIRED ANODE VOLTAGE
FOR VTM TUBES, = REQUIRED INJECTOR VOLTAGE
30 40 50 60 70 80 90 100 120 140 160 180 200 220 240 260 280
A12R14 IN KΩ FOR BWO PLUG-IN UNITS OR VTM PLUG-IN UNITS
0 100 200 300 400 500 600 700 800 900
R (K Ω) = OUTPUT E + 1.92 / .384

FIGURE 5-8. GRAPH OF ANODE FEEDBACK RESISTOR VALUES VS REQUIRED ANODE SUPPLY OUTPUT VOLTAGE FOR PLUG-IN UNITS

MAINTENANCE NOTES

PC BOARD ASSEMBLIES

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TOTAL QTY.
A1	950813	Cathode Supply PC Board	1
A2	950818	Low-Voltage Supply PC Board	1
A3	951045	Sweep PC Board	1
A4	950911	Markers PC Board	1
A5	950619	Modulator PC Board	1
A6	950731	Auxiliary Supply PC Board	1
A7	950624	Helix Overcurrent PC Board	1
A9	950635	Transfer Oscillator PC Board	1
A10	951083	Series Regulator/Retrace Discharge Assembly (these parts included in "main chassis assembly" in S/N 1050 & below and are listed with a double asterisk (**) to indicate use of A10 prefix in S/N 1051 & above)	1
A11	*	Leveler-Amplifier PC Board	1
A12	*	Elevated Supply PC Board	1
A13	*	Diode Shaper PC Board	1
A15	951061	Rectifier Assembly (these parts included in main chassis assembly in S/N 1090 & below)	1
A19	*	[V]Anode Protection PC Board	1
A26	951249	Bleeder PC Board	1

*See separate Manual for Plug-in Unit.. [V]Used with Varian tubes only.

MAIN CHASSIS PARTS

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
C1	13-54	Capacitor, fixed, elect., 80/50 mf, 150 v
C2	13-38	Capacitor, fixed, elect., 100 mf, 250 v
C3	13-46	Capacitor, fixed, elect., 150 mf/150 v; 100 mf/50 v
C4 and C5	15-21	Capacitor, fixed, oil, 2 mf, 2 kv
C6 and C7	12-28	Capacitor, fixed, ceramic, 0.001 mf, 6kv
		Not used (S/N 1091 and above)
	13-52	Capacitor, fixed, elect., 60/60 mf, 450 v
C9	13-53	Capacitor, fixed, elect., 200/200 mf, 150 v
C10	13-9	Capacitor, fixed, elect., 3000 mf, 15 v
C11		Same as C2
C12	13-36	Capacitor, fixed, elect., 100/100 mf, 50 v
C13	13-35	Capacitor, fixed, elect., 500 mf, 25 v
C14	14-10	Capacitor, fixed, paper, 0.005 mf, 6 kv
C15**		Same as C6
C16		Same as C14
C20**	12-2	Capacitor, fixed, ceramic, 0.001 mf, 500 v (S/N 930 & below)
	12-9	Capacitor, fixed, ceramic, 0.05 mf, 75 v, 20% (S/N 931 & up)
C21	13-62	Capacitor, fixed, ceramic, 100mf,50v (S/N 1091 & up)
	13-28	Capacitor, fixed, ceramic, 25mf,50v (S/N 1090 & below)
C22	12-34	Capacitor, fixed, ceramic, 0.1 mf, 100 v
C23 and C24	12-33	Capacitor, fixed, ceramic, 0.01mf, 3000 v[tt]
C25**	12-3	Capacitor, fixed, ceramic, 0.01 mf, 1000 v, 20% (S/N 931 & up)
CR1 thru CR7	81-20	Diode, DI-46/1N4385 } Replaced by components on A15, S/N 1091 & up
CR8	81-69	Diode, DI-1154 } Replaced by components on A15, S/N 1091 & up
CR9 thru CR16		Same as CR1 } Replaced by components on A15, S/N 1091 & up
CR17 and CR18	81-82	Diode, MR322 } Replaced by components on A15, S/N 1091 & up
CR19** and CR20	81-41	Diode, 1N459 } Replaced by components on A15, S/N 1091 & up
CR21 and CR22		Same as CR1 } Replaced by components on A15, S/N 1091 & up
CR23	81-41	Diode, 1N459
CR24	81-41	Diode, 1N459
CR25**	81-138	Diode, 1N4757 (S/N 931 & up)
CR26 thru CR28	81-20	Diode, 1N4385 (S/N 931 & up) } Replaced by components on A15, S/N 1091 & up

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
Q1	81-89	Transistor, 2N1537
Q2	81-112	Transistor, RCA 40251
Q3 and Q4	81-86	Transistor, 2N2147
Q5		Same as Q2
Q6**	81-72	Transistor, 2N699 (S/N 930 & below)
	81-115	Transistor, 2N3565 (S/N 931 & up)
Q7**	81-137	Transistor 2N3568 (S/N 931 & up)
R1	61-15	Resistor, fixed, WW, 3.6 Ω, 5 w (S/N 1050 & below)
R2	41-10 Ω	Resistor, fixed, comp., 10 Ω, 1/2 w, 10%
R3	41-100 K	Resistor, fixed, comp., 100 K, 1/2 w, 10%
R4		Not used
R5	43-68 Ω	Resistor, fixed, comp., 68 Ω, 2 w, 10%
R6		Same as R3
R7	41-10 K	Resistor, fixed, comp., 10 K, 1/2 w, 10%
R8	41-15 K	Resistor, fixed, comp., 15 K, 1/2 w, 10%
R9		Same as R7
R10 and R11		Same as R2 (S/N 1090 & below)
		Not used (S/N 1091 and above)
R12**	41-1 K	Resistor, fixed, comp., 1 K, 1/2 w, 10%
R13**	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10%
R14**	41-1K	Resistor, fixed, comp., 1 K, 1/2 w, 10% (S/N 930 & below)
	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10% (S/N 931 & up)
R15**		Same as R12
R16**		Same as R13
R17**	41-1K	Resistor, fixed, comp., 1 K, 1/2 w, 10% (S/N 930 & below)
	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10% (S/N 931 & up)
R18**		Same as R12
R19**		Same as R13
R20**	41-1K	Resistor, fixed, comp., 1 K, 1/2 w, 10% (S/N 930 & below)
	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10% (S/N 931 & below)
R21**	42-15 K	Resistor, fixed, comp., 15 K, 1 w, 10%
R22**	42-10 K	Resistor, fixed, comp., 10 K, 1 w, 10%
R23**	43-68 K	Resistor, fixed, comp., 68 K, 2 w, 10%
R24**	41-22 K	Resistor, fixed, comp., 22 K, 1/2 w, 10%

[tt] = S/N 1250 & below only

t = not used in units which have R84 - R87.

** = Part of Regulator/Retrace Discharge Assembly - use A10 prefix in S/N 1051 & up.

MAIN CHASSIS PARTS (continued)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
R25**	63-17	Resistor, fixed, WW, 10 K, 20 w, 5% (S/N 930 & below and S/N 1051 & up)
	62-10	Resistor, fixed, WW, 5 K, 10 w, 5% (S/N 931 - 1050)
R26**	62-1	Resistor, fixed, WW, 10 K, 10 w, 5% (S/N 930 & below)
	62-10	Resistor, fixed, WW, 5 K, 10 w, 5% (S/N 931 - 1050)
R27**		Same as R12
R28	41-150 K	Resistor, fixed, comp., 150 K, 1/2 w, 10%
R29	41-27 Ω	Resistor, fixed, comp., 27 Ω, 1/2 w, 10%
R30	71-71	Resistor, variable, 5 M, 1/2 w, 10%
R31	56-374 K	Resistor, fixed, MF, 37[illegible] K, 1/2 w, 1%
R32		Same as R7
R33	61-13	Resistor, fixed, WW, 2.5 K, 5 w, 10%
R34	(102-139)	Resistor, variable, 10K (part of S15 assy.)
R35		Same as R12
R36		Resistor, variable (part of S12) 100K (S/N 1170 & below)††; 10K (S/N 1171 & up)
R37	71-97	Resistor, variable, 10 K, 20%
R38	74-6	Resistor, variable, 1 K, 10 turn, 1%
R39 and R40	41-33 Ω	Resistor, fixed, comp., 33 Ω, 1/2 w, 10%
R41		Same as R38
R42	71-72	Resistor, variable, 100 Ω, 2 w, 10%
R43		Same as R39
R44		Same as R38
R45		Same as R39
R46		Same as R38
R47		Same as R39
R48		Same as R38
R49	61-22	Resistor, fixed, WW, 8 M, 4 w, 5 kv (S/N [illegible])
R50	41-2.2 K	Resistor, fixed, comp., 2.2 K, 1/2 w, 10%
R51	45-9.1 Ω	Resistor, fixed, comp., 9.1 Ω, 1 w, 5% (S/N 930 & below)
	61-23	Resistor, fixed, WW, 3 Ω, 5 w (S/N 931 - 1050)
R52**		Same as R13
R53**	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10% (S/N 930 & below)
	41-1 K	Resistor, fixed, comp., 1 K, 1/2 w, 10% (S/N 931 & up)
R54**	56-53.6 K	Factory selected (S/N 930 & below)
	56-178 K	Resistor, fixed, MF, 1/2 w, 1% (S/N 931 & up)
R55**	41-390 K	Resistor, fixed, comp., 390 K, 1/2 w, 10% (S/N 930 & below)
	41-2.7 K	Resistor, fixed, comp., 2.7 K, 1/2 w, 10% (S/N 931 & up)
R56**	56-3.83 K	Resistor, fixed, MF, 3.83 K, 1/2 w, 1% (S/N 930 & below)
	51-820 Ω	Resistor, fixed, dep., carbon, 1/2 w, 5% (S/N 931 & up)
R57**	41-220 K	Resistor, fixed, comp., 220 K, 1/2 w, 10% (S/N 930 & below)
	41-12 K	Resistor, fixed, comp., 12 K, 1/2 w, 10% (S/N 931 & up)
R58**	41-8.2 M	Resistor, fixed, comp., 8.2 M, 1/2 w, 10%
R59**		Same as R3
R60		Same as R12
R61	41-6.8 K	Resistor, fixed, comp., 6.8 K, 1/2 w, 10%
R62	56-38.3 Ω	Resistor, fixed, MF, 38.3 Ω, 1/2 w, 1%
R63		Same as R3
R64 and R65	41-470 K	Resistor, fixed, comp., 470 K, 1/2 w, 10%
R66	56-18.7 K	Resistor, fixed, MF, 18.7 K, 1/2 w, 1%
R67		Not used
R68		Not used
R69		Not used
R70		Not used
R71 thru R75	71-102	Resistor, variable, 100 Ω

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
R76**	41-1 K	Resistor, fixed, comp., 1 K, 1/2 w, 10% (S/N 930 & below)
	41-330 Ω	Resistor, fixed, comp., 330 Ω, 1/2 w, 10% (S/N 931 & up)
R77		Same as R13
R78	41-82 K	Resistor, fixed, comp., 82 K, 1/2 w, 10%
R79	41-1 K	Resistor, fixed, comp., 1 K, 1/2 w, 10%
R80†	41-10 K	Resistor, fixed, comp., 10 K, 1/2 w, 10%
R81†	41-4.7 K	Resistor, fixed, comp., 4.7 K, 1/2 w, 10%
R82**	42-470 K	Resistor, fixed, comp., 470 K, 1 w, 10% (S/N 931 & up)
R83**	41-1 K	Resistor, fixed, comp., 1 K, 1/2 w, 10% (S/N 931 & up)
R84 thru R87	39-4.7 M	Resistor, fixed, dep. carbon, 4.7 M, 1/2 w, 1% (installed as required)
R92	41-10 K	Resistor, fixed, comp., 10K, 1/2 w, ±10% Not used (S/N 1171 and above)
T1	91-195	Transformer, Power, ALFRED Spec. #950601C
T2	91-196	Transformer, Power, ALFRED Spec. #950611C
K1	106-25	Relay, time delay (Amperite 6N060T)
K2 and K3	106-30	Relay, 100 v dc (KA1466)
K4	106-24	Relay, P & B, RS5D-10 K
S1	101-3	Switch, toggle, DPST
S2	101-21	Switch, snap action, lever
S3	102-128	Switch, lever
S4	101-8	Switch, pubhbutton (normally closed)
S5 and S6	101-17	Switch, interlock
S7	101-19	Switch, pushbutton, Switchcraft 963
S8		Part of R37 (CTS-45 Series)
S9	101-18	Switch, pushbutton, Switchcraft 201 (sweep trigger)
S10	102-122	Switch, rotary, 630905 (sweep trigger)
S11	102-121	Switch, rotary, 630903 (sweep time)
S12	102-135	Switch, rotary, 630904 (modulation)
S13		Not used
S14	102-138	Switch, rotary, 650914
S15	102-139	Switch, rotary, (includes R34/S17)
S16	102-136	Switch, slide
S17	(102-139)	Switch, DPDT, (part of S15 assy.)
V1** thru V3**	111-8068	Tube, electron, 8068
V4**	111-6CW5	Tube, electron, 6CW5
V5**	111-7239	Tube, electron, 7239 (S/N 930 & below)
	111-8068	Tube, electron, 8068 (S/N 931 & up)
F1	121-23	Fuse, 1.2 amp., Type 3AG, Slo-blo
F2	121-26	Fuse, 3 amp., Type 3AG, Slo-blo
F3	121-14	Fuse, 2 amp., Type 3AG, Slo-blo
DS1 and DS2	126-9	Bulb, indicator, panel (Leecraft #32-1111T)
DS3	126-1	Bulb, lamp, neon, NE-2
DS4	126-11	Bulb, lamp, neon, NE-2 in plastic case (Drake #116-303)
RT1	40-10	Thermistor (S/N 930 & below) Deleted (S/N 931and above)

Revised 2/15/68

† = not used in units which have R84 - R87

** = Part of Regulator/Retrace Discharge Assembly - use A10 prefix in S/N 1051 & up.

†† = If 10 K value is used for replacement, remove R92 which is connected in parallel in units having 100 K potentiometer.

A1 PC BOARD ASSEMBLY PARTS

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
A1C1 and A1C2	12-3	Capacitor, fixed, ceramic, 0.01 mf, 500 v
A1C3	12-2	Capacitor, fixed, ceramic, 0.001 mf, 500 v (S/N 930 & below)
	12-9	Capacitor, fixed, ceramic, 0.05 mf, 75 v, 20% (S/N 931 & up)
A1C4		Not used
A1C5	12-9	Capacitor, fixed, ceramic, 0.05 mf, 75 v
A1C6	12-15	Capacitor, fixed, ceramic, 0.002 mf, 500v
A1C7	12-34	Capacitor, fixed, ceramic, 0.1 mf, 100 v
A1C8 and A1C9	12-34	Capacitor, fixed, ceramic, 0.1 µf, 100 v,
A1C10	12-27	Capacitor, fixed, ceramic, 270 pf, 500 v
A1C11	14-13	Capacitor, fixed, paper, 1 µf, 200 v
A1C12 and A1C13	12-34	Capacitor, fixed, ceramic, 0.1 mf, 100 v
A1C14	12-22	Capacitor, fixed, ceramic, 100 pf, 1 kv
A1CR1	81-88	Diode, 1N3041A
A1CR2 and A1CR3	81-20	Diode, DI-46/1N4385
A1CR4	81-77	Diode, 1N752A; Alt: PSI 18199
A1CR5	81-132	Diode, 1N914 (installed as required)
A1Q1	81-113	Transistor, 950680, SP9965 or NS7301
A1Q2 thru A1Q5	81-116	Transistor, 2N3646/S18563
A1Q6 and A1Q7	81-72	Transistor, 2N699 (S/N 930 & below)
	81-115	Transistor, 2N3565 (S/N 931 & up)
A1Q8 and A1Q9	81-115	Transistor, 2N3565
A1Q10 and A1Q11		Same as A1Q1
A1Q12 and A1Q13	81-114	Transistor, 2N3638A
A1R1	41-15 K	Resistor, fixed, comp., 15 K, 1/2 w, 10%
A1R2	41-33 K	Resistor, fixed, comp., 33 K, 1/2 w, 10%
A1R3 thru A1R5	57-15 K	Resistor, fixed, MF, 15 K, 1/2 w, 1/2%
A1R6	56-14.7 K	Resistor, fixed, MF, 14.7 K, 1/2 w, 1%
A1R7	41-22 K	Resistor, fixed, comp., 22 K, 1/2 w, 10%
A1R8	41-470 Ω	Resistor, fixed, comp., 470 Ω, 1/2 w, 10%
A1R9	41-15 K	Resistor, fixed, comp., 15 K, 1/2 w, 10%
A1R10		Same as A1R7
A1R11	41-2.2 K	Resistor, fixed, comp., 2.2 K, 1/2 w, 10%
A1R12*	41-330 Ω	Resistor, fixed, comp., 330 Ω, 1/2 w, 10%
A1R13	41-3.9 K	Resistor, fixed, comp., 3.9 K, 1/2 w, 10%
A1R14		Same as A1R11
A1R15*		Resistor, factory select, nominal value 47Ω
A1R16	41-1.2 K	Resistor, fixed, comp., 1.2 K, 1/2 w, 10%
A1R17	41-27 K	Resistor, fixed, comp., 27 K, 1/2 w, 10%
A1R18	43-3.9 K	Resistor, fixed, comp., 3.9 K, 2 w, 10%
A1R19	42-4.7 K	Resistor, fixed, comp., 4.7 K, 1 w, 10%
A1R20	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10%
A1R21	56-392 K	Resistor, fixed, MF, 392 K, 1/2 w, 1%
A1R22	56-221 K	Resistor, fixed, MF, 221 K, 1/2 w, 1%
A1R23	41-47 K	Resistor, fixed, comp., 47 K, 1/2 w, 10%
A1R24	71-94	Resistor, variable, 20 turn, 5 k
A1R25	41-100 K	Resistor, fixed, comp., 100 K, 1/2 w, 10%
A1R26	41-10 K	Resistor, fixed, comp., 10 K, 1/2 w, 10%
A1R27	41-4.7 K	Resistor, fixed, comp., 4.7 K, 1/2 w, 10%
A1R28	41-1 K	Resistor, fixed, comp., 1 K, 1/2 w, 10%
A1R29 and A1R30	56-4.99 K	Resistor, fixed, MF, 4.99 K, 1/2 w, 1%
A1R31	41-1.5 K	Resistor, fixed, comp., 1.5 K, 1/2 w, 10%
A1R32		Same as A1R7
A1R33		Same as A1R26
A1R34	35-6.8 K	Resistor, fixed, MF, 6.8 K, 2 w, 5%
A1R35		Same as A1R31
A1R36		Same as A1R7
A1R37		Same as A1R26
A1R38	71-91	Resistor, variable, 20 turn, 500 Ω
A1K1	106-29	Relay, 6 v dc (P & B, RS5D)

A2 PC BOARD ASSEMBLY PARTS

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
A2C1 thru A2C5	12-34	Capacitor, fixed, ceramic, 0.1 mf, 100 v
A2C6	12-3	Capacitor, fixed, ceramic, .01 mf. 500v
A2C7	13-40	Capacitor, fixed, elect., 100 mf, 10 v
A2C8	13-33	Capacitor, fixed, elect., 10 mf, 100 v
A2C9		Same as A2C1
A2C10		Same as A2C6
A2CR1	81-75	Diode, 1N823
A2CR2 and A2CR3	81-41	Diode, 1N459
A2Q1	81-71	Transistor, 2N697
A2Q2 and A2Q3	81-114	Transistor, 2N3638A
A2Q4	81-113	Transistor, 950672, SP9965 or NS7301
A2Q5 thru A2Q7		Same as A2Q3
A2Q8		Same as A2Q4
A2Q9 and A2Q10		Same as A2Q3
A2Q11		Same as A2Q4
A2Q12		Same as A2Q3
A2Q13	81-72	Transistor, 2N699 (S/N 930 & below)
	81-115	Transistor, 2N3565 (S/N 931 & up)
A2R1	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10%
A2R2	43-10 K	Resistor, fixed, comp., 10 K, 2 w, 10%
A2R3	41-15 K	Resistor, fixed, comp., 15 K, 1/2 w, 10%
A2R4	56-19.6 K	Resistor, fixed, MF, 19.6 K, 1/2 w, 1%
A2R5	44-1 Ω	Resistor, fixed, BW, 1 Ω, 1/2 w, 5%
A2R6 and A2R7		Same as A2R4
A2R8	41-22 Ω	Resistor, fixed, comp., 22 Ω, 1/2 w, 10%
A2R9	71-90	Resistor, variable, 200 Ω, 20 turn, WW
A2R10 and A2R11	56-1.21 K	Resistor, fixed, MF, 1.21 K, 1/2 w, 1%
A2R12		Same as A2R5
A2R13	41-1.5 K	Resistor, fixed, comp., 1.5 K, 1/2 w, 10%
A2R14	41-8.2 K	Resistor, fixed, comp., 8.2 K, 1/2 w, 10%
A2R15		Same as A2R3
A2R16	41-820 Ω	Resistor, fixed, comp., 820 Ω, 1/2 w, 10%
A2R17	56-750 Ω	Resistor, fixed, MF, 750 Ω, 1/2 w, 1%
A2R18		Same as A2R9
A2R19		Same as A2R10
A2R20 thru A2R22		Same as A2R4
A2R23	41-330 Ω	Resistor, fixed, comp., 330 Ω, 1/2 w, 10%
A2R24		Same as A2R10
A2R25	41-33 K	Resistor, fixed, comp., 33 K, 1/2 w, 10%
A2R26		Same as A2R3
A2R27	56-4.99 K	Resistor, fixed, MF, 4.99 K, 1/2 w, 1%
A2R28	56-34 K	Resistor, fixed, MF, 34 K, 1/2 w, 1%
A2R29 and A2R30	41-470 Ω	Resistor, fixed, comp., 470 Ω, 1/2 w, 10%
A2R31	56-15 K	Resistor, fixed, MF, 15 K, 1/2 w, 1%
A2R32	56-49.9 K	Resistor, fixed, MF, 49.9 K, 1/2 w, 1%
A2R33		Same as A2R1
A2R34*	41-10 Ω	Resistor, fixed, comp., 10 Ω, 1/2 w, 10%
A2R35	41-5.6 K	Resistor, fixed, comp., 5.6 K, 1/2 w, 10%
A2R36		Same as A2R29
A2R37		Same as A2R1
A2R38	41-1.2 K	Resistor, fixed, comp., 1.2 K, 1/2 w, 10%
A2R39		Same as A2R3
A2R40	41-2.2 K	Resistor, fixed, comp., 2.2 K, 1/2 w, 10%
A2R41 and A2R42	41-3.3 K	Resistor, fixed, comp., 3.3 K, 1/2 w, 10%

*Factory Selected

SECTION 7

SCHEMATIC DIAGRAMS

Schematics are included in the following order:

OVERALL CHASSIS SCHEMATIC (as applicable to instrument S/N)	(900775D) Rev 27 (S/N 930 & below) (900775D) Rev GG (S/N 931 - 1050) (900775D) Rev HH (S/N 1051 - 1090) (900755D) Rev KK (S/N 1091 - 1250) (900755D) Rev RR (S/N 1251 & up)
CATHODE SUPPLY PC BOARD A1	(900770C)
LOW-VOLTAGE SUPPLY PC BOARD A2	(900766C)
SWEEP PC BOARD A3 (as applicable to instrument S/N)	(900732C - S/N 890 & below) (900887C - S/N 891 & up)
MARKERS PC BOARD A4	(900733C)
MODULATOR PC BOARD A5	(900714C)
AUXILIARY SUPPLY PC BOARD A6	(900757C)
HELIX OVERCURRENT PC BOARD A7	(900731C)
TRANSFER OSCILLATOR PC BOARD A9	(900747C)
SERIES REGULATOR/RETRACE DISCHARGE ASSY A10 (S/N 1051 & up)	(C900906)
RECTIFIER ASSEMBLY BOARD A15 (S/N 1091 & up)	(C900905)
BLEEDER BOARD ASSEMBLY A26 (S/N 1251 & up)	(C900955)

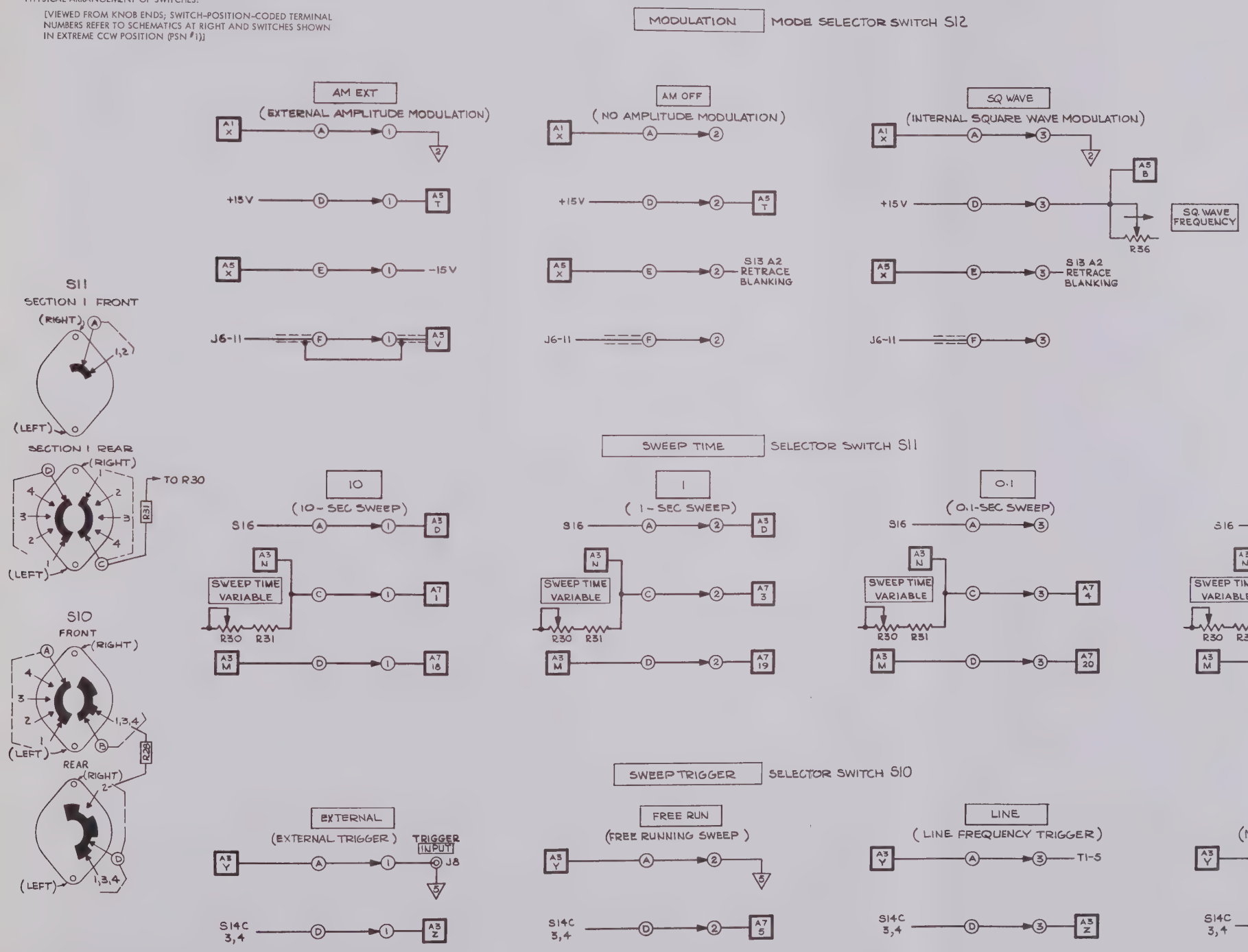
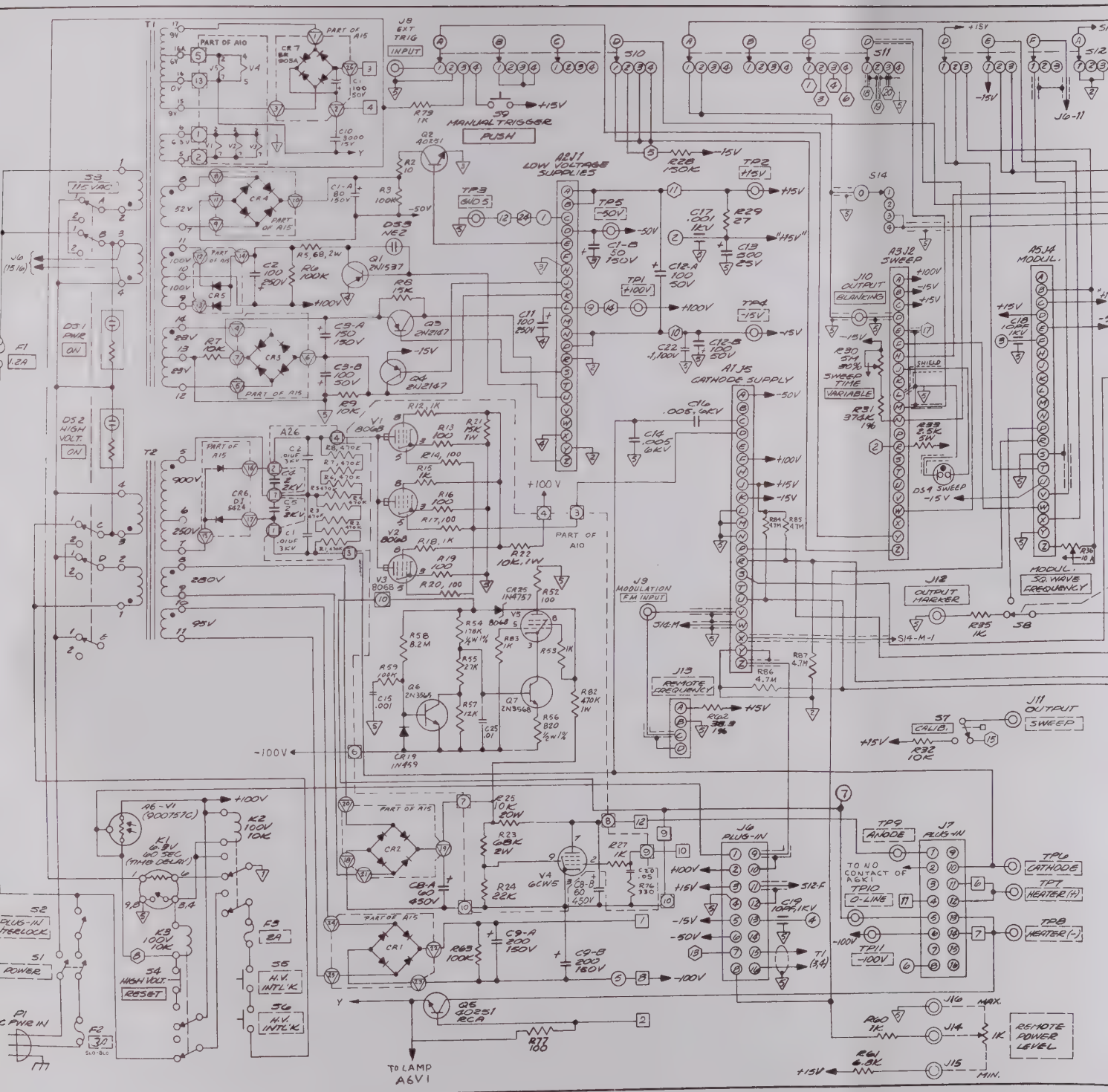
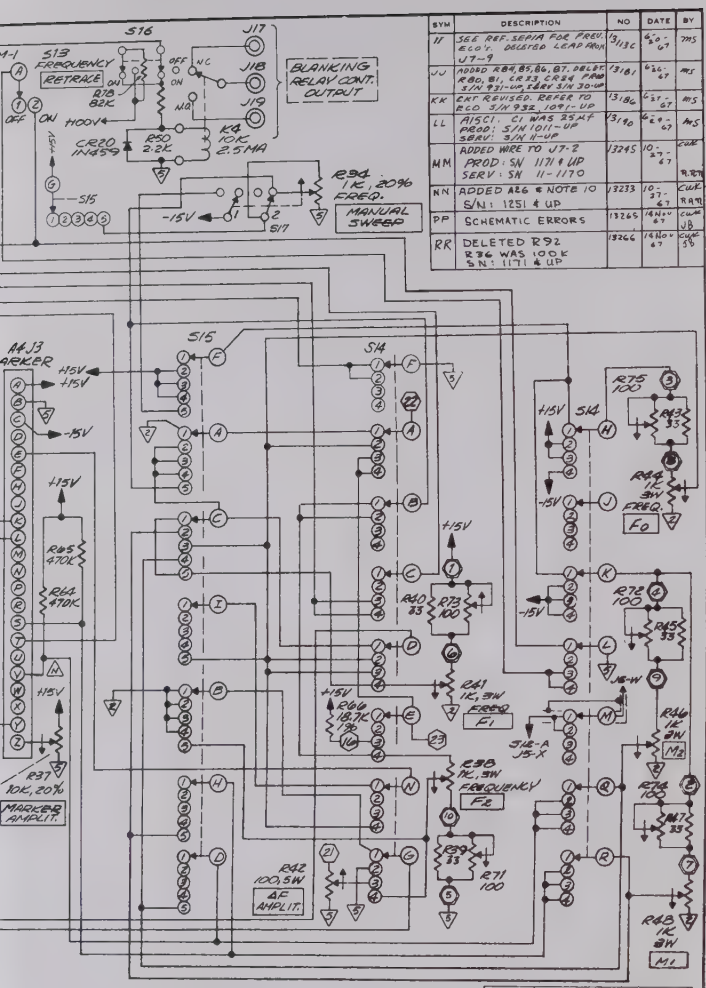


FIGURE 4-18. SCHEMATIC AND WIRING DI
SWEEP TIME AND SWEEP TRIGGER SELECTO


T1
PART OF A10
PART OF A15
CR7
CR4
CR5
CR3
CR6
V4
V5
V1
V2
V3
T2
J8
EXT TRIG
INPUT
S9
MANUAL TRIGGER
PUSH
Q2
40251
R2
10
D33
NEZ
Q1
2N1537
Q3
2N2147
Q4
2N2147
R4
100K
R6
13K
R7
10K
R8
470E
R9
470K
R10
470K
R11
470K
R12
1K
R13
100
R14
100
R15
1K
R16
100
R17
100
R18
1K
R19
100
R20
100
R21
15K
1W
R22
10K
1W
R23
68K
2W
R24
22K
R25
10K
20W
R27
1K
R28
150K
R29
27
R30
5M
30%
SWEEP TIME
VARIABLE
R31
374K
1%
R32
10K
R33
2.5K
5W
R36
10
R52
100
R54
178K
1/2W 1%
R55
27K
R56
820
1/2W 1%
R57
12K
R58
8.2M
R59
100K
R82
470K
1W
R84
4.7M
R85
4.7M
R86
4.7M
R87
4.7M
R92
1%
R95
1K
C1
100
50V
C1-A
80
150V
C1-B
50
150V
C2
100
250V
C3-A
150
150V
C3-B
100
50V
C4
.01UF
3KV
C5
.01UF
3KV
C6
2UF
2KV
C8-A
60
450V
C8-B
60
450V
C9-A
200
150V
C9-B
200
150V
C10
3000
15V
C11
100
250V
C12-A
100
50V
C12-B
100
50V
C13
300
25V
C15
.001
C16
.005, 6KV
C17
.001
1KV
C18-A
100
50V
C18-B
100
50V
C19
1000PF, 1KV
C22
.1,100V
C25
.01
CR35
IN4757
CR19
IN459
A2J1
LOW VOLTAGE SUPPLIES
A1J5
CATHODE SUPPLY
A3J2
SWEEP
A5J4
MODUL.
J10
OUTPUT
BLANKING
J11
OUTPUT
SWEEP
J12
OUTPUT
MARKER
J13
REMOTE
FREQUENCY
J14
REMOTE
POWER
LEVEL
J16
MAX.
J15
MIN.
J9
MODULATION
FM INPUT
J6
PLUG-IN
J7
PLUG-IN
S3
115 VAC
S2
INTERLOCK
S1
POWER
S4
HIGH VOLT.
RESET
S7
CALIB.
S10
S11
S12
S13
S14
F1
1.2A
F2
3A SLO-BLO
F3
2A
DS1
PWR
ON
DS2
HIGH VOLT.
ON
DS4
SWEEP
-15V
H.V. INT'L K
H.V. INT'L K
TP1
+100V
TP2
+15V
TP3
GND S
TP4
-15V
TP5
-50V
TP6
CATHODE
TP7
HEATER (+)
TP8
HEATER (-)
TP9
ANODE
TP10
D-LINE
TP11
-100V
TO NO CONTACT OF KK1
A6-V1
(9007S7C)
K1
6.3V
60 SEC
(TIME DELAY)
K2
100V
10K
K3
100V
10K
Q5
40251
RCA
R77
100
R60
1K
R61
6.8K
TO LAMP
A6V1
+100V
-100V
+15V
-15V
-50V
+150V
+1000V
S12-F
S14-M-1
J6-11
-15V
+15V
+100 V
PART OF A10
PART OF A15
PART OF A15
PART OF A15



SYM	DESCRIPTION	NO	DATE	BY
II	SEE REF. SERIA FOR PREV. ECO'S. DELETED LEAD FROM J17-9	13136	6-20-67	TMS
JJ	ADDED R84, 85, 86, 87. DELET R80, 81, CR33, CR34 FROM S/N 921-UP, EXP S/N 3010	13181	6-26-67	MS
KK	EXT REVISED. REFER TO ECO S/N 932, 1091-UP	13186	6-27-67	MS
LL	AISCI. CI WAS 33 μF MEGO: S/N 1011-UP SBRV: S/N 11-UP	13190	6-29-67	MS
MM	ADDED WIRE TO J7-2 PROD: SN 1171 & UP SERV: SN 11-1170	13245	10-27-67	CWC R.R.M.
NN	ADDED A26 & NOTE 10 S/N: 1251 & UP	13233	10-27-67	CWC R.R.M.
PP	SCHEMATIC ERRORS	13265	11-10-67	CWC JB
RR	DELETED R92 R36 WAS 100K SN: 1171 & UP	13266	11-10-67	CWC JB

NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTORS IN OHMS, 1/2 W, 10%
   - 1B. ALL CAPACITORS IN MICROFARADS, 500 V
   - 1C. ALL ROTARY SWITCHES SHOWN IN CCW POSITION
   - 1D. ALL RELAYS SHOWN IN DE-ENERGIZED POSITION
   - 1E. ARROWS ON ALL POTENTIOMETERS INDICATES CW ADJUSTMENT
   - 1F. ALL VOLTAGES RELATIVE TO GROUND
2. (J13 — REMOTE FREQUENCY CONNECTOR) REFER TO INSTRUCTION MANUAL FOR DETAILED INSTRUCTIONS FOR REMOTE FREQUENCY OPERATION.
3. CIRCLE IN HEXAGON (⬡) INDICATES TERMINAL CONNECTION ON "IN VOLTAGE CALIBRATE" PRINTED CIRCUIT BOARD
4. TRIANGLE (▽) INDICATES GROUND CONNECTION
5. HEXAGON (⬡) INDICATES TERMINAL CONNECTION ON HELIX OVERCURRENT PRINTED CIRCUIT BOARD A7.
6. SQUARE (□) INDICATES TERMINAL CONNECTION ON AUXILIARY SUPPLY PRINTED CIRCUIT BOARD A6.
7. CIRCLE (○) INDICATES TERMINAL CONNECTION ON TRANSFER OSCILLATOR PRINTED CIRCUIT BOARD A9.
8. CIRCLE IN SQUARE (▣) INDICATES TERMINAL CONNECTION ON SERIES REGULATOR/RETRACE DISCHARGE PRINTED CIRCUIT BD (A10)
9. TRIANGLE IN CIRCLE (▽) INDICATES TERMINAL CONNECTION ON RECTIFIER BD. (A15)
10. SQUARE IN CIRCLE (▣) INDICATES TERMINAL CONN ON A26

SWITCH	SWITCH POSITION	MODE OF OPERATION
S10	1	EXTERNAL
S10	2	FREE RUN
S10	3	LINE
S10	4	MANUAL
S11	1	10
S11	2	1.0
S11	3	0.1
S11	4	.01
S12	1	AM EXTERNAL
S12	2	AM OFF
S12	3	SQ. WAVE
S14	1	SINGLE
S14	2	OFF
S14	3	FO ± ΔF
S14	4	F_1 F_2
S15	1	F_1
S15	2	M_1
S15	3	F_0
S15	4	M_2
S15	5	F_2

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

14P1E UP

650

NEXT ASSY | USED ON

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

		DATE
DRAWN		12-5-64
ENG	A. Nelson	2-16-65
PROD		2-16-65
SCALE		

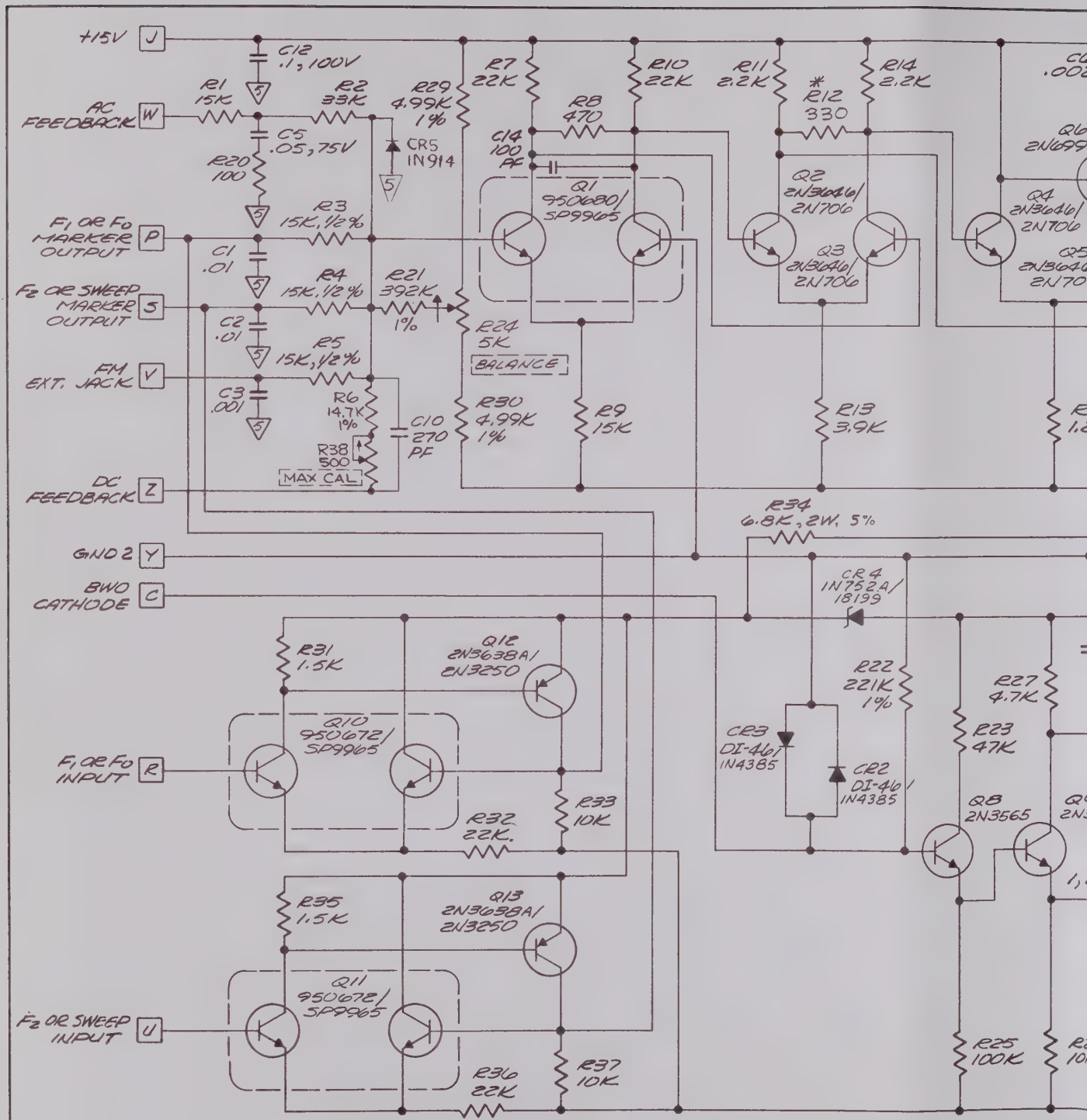
SCHEMATIC SWEEP SIGNAL OSCILLATOR

DIMENSIONS ARE IN INCHES
TOL .XX ± .015, .XXX ± .005, ANGLE ± 1°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE D | 900775 | REV TT

SHEET 1 OF 1



* INDICATES FACTORY SELECTED

NOTES:

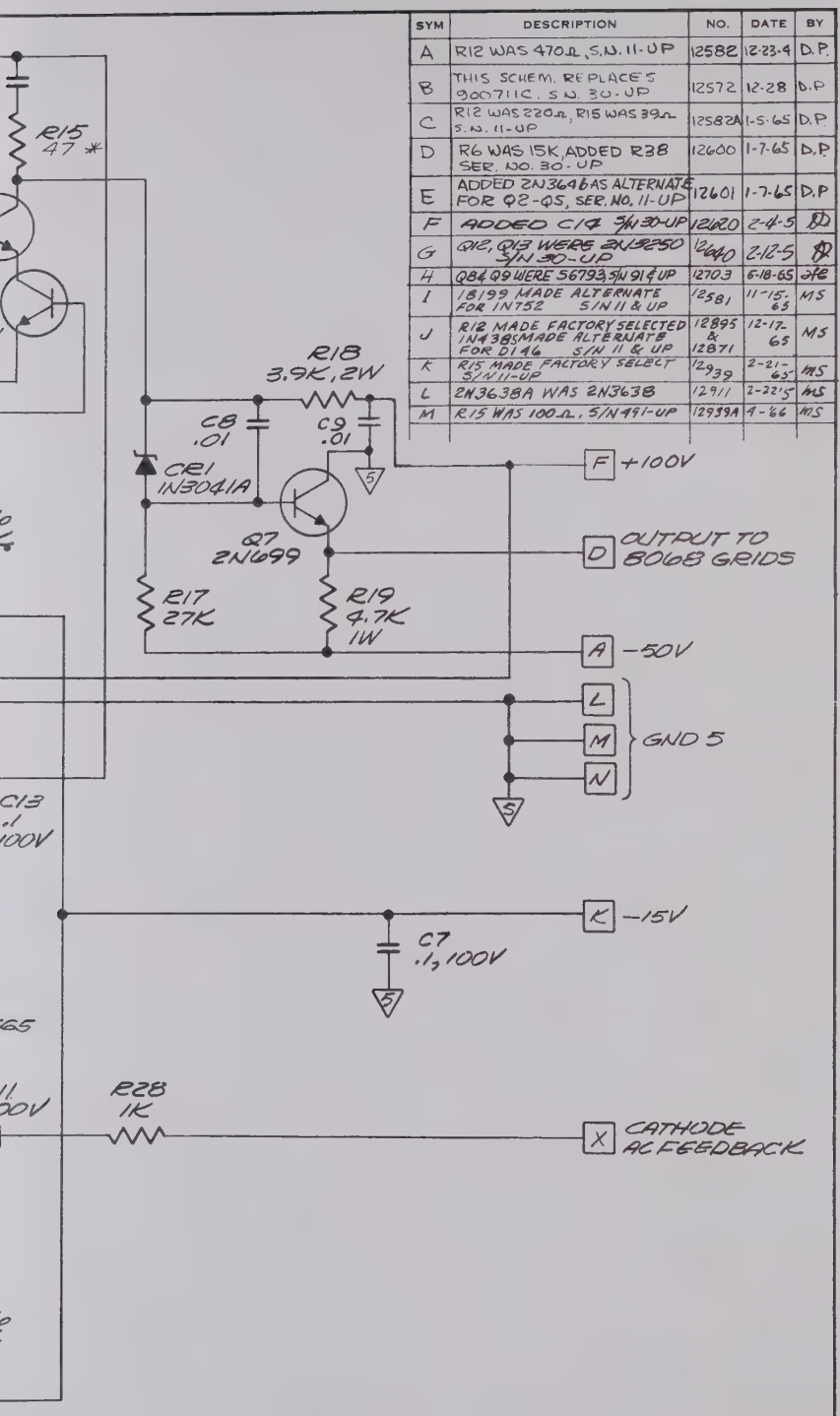
1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   - 1B. ALL RESISTORS 1/2% AND 1% ARE METAL FILM
   - 1C. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A1", ASSEMBLY NO. 950813
3. PREFIX REFERENCE DESIGNATOR BY "A1" (IE: A1R1, A1Q13)

ITEM	REQD	PART NO.

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT



SYM	DESCRIPTION	NO.	DATE	BY
A	R12 WAS 470Ω, S.N. 11-UP	12582	12-23-4	D.P.
B	THIS SCHEM. REPLACES 900711C. S.N. 30-UP	12572	12-28	D.P.
C	R12 WAS 220Ω, R15 WAS 39Ω S.N. 11-UP	12582A	1-5-65	D.P.
D	R6 WAS 15K, ADDED R38 SER. NO. 30-UP	12600	1-7-65	D.P.
E	ADDED 2N3646 AS ALTERNATE FOR Q2-Q5, SER. NO. 11-UP	12601	1-7-65	D.P.
F	ADDED C14 S/N 30-UP	12620	2-4-5	DP
G	Q12, Q13 WERE 2N5250 S/N 30-UP	12640	2-12-5	DP
H	Q8 & Q9 WERE 56793, S/N 91 & UP	12703	6-18-65	JHE
I	1B199 MADE ALTERNATE FOR 1N752 S/N 11 & UP	12581	11-15-65	MS
J	R12 MADE FACTORY SELECTED 1N4385 MADE ALTERNATE FOR D14G S/N 11 & UP	12895 & 12871	12-17-65	MS
K	R15 MADE FACTORY SELECT S/N 11-61P	12939	2-21-65	MS
L	2N3638A WAS 2N3638	12911	2-22'5	MS
M	R15 WAS 100Ω, S/N 491-UP	12939A	4-66	MS

DESCRIPTION	
LIST OF MATERIAL	
SER NO. 30-UP	650
NEXT ASSY	USED ON

DRAWN	Ethel G. Stone	DATE 12-1-64
ENG	[illegible]	12-16-64
PROD	[illegible]	12-15-64
SCALE		

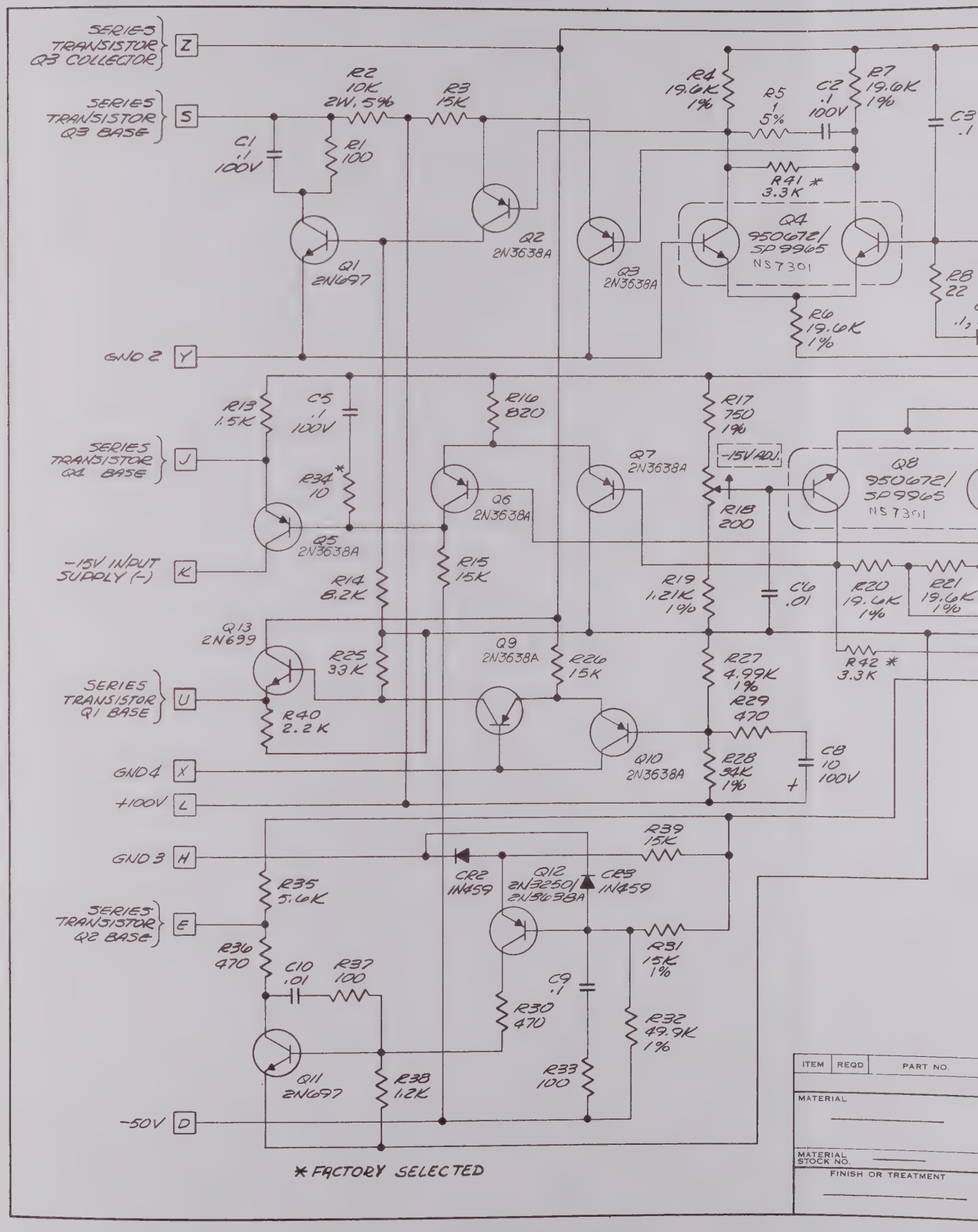
SCHEMATIC
CATHODE SUPPLY
& FEEDBACK CKT

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

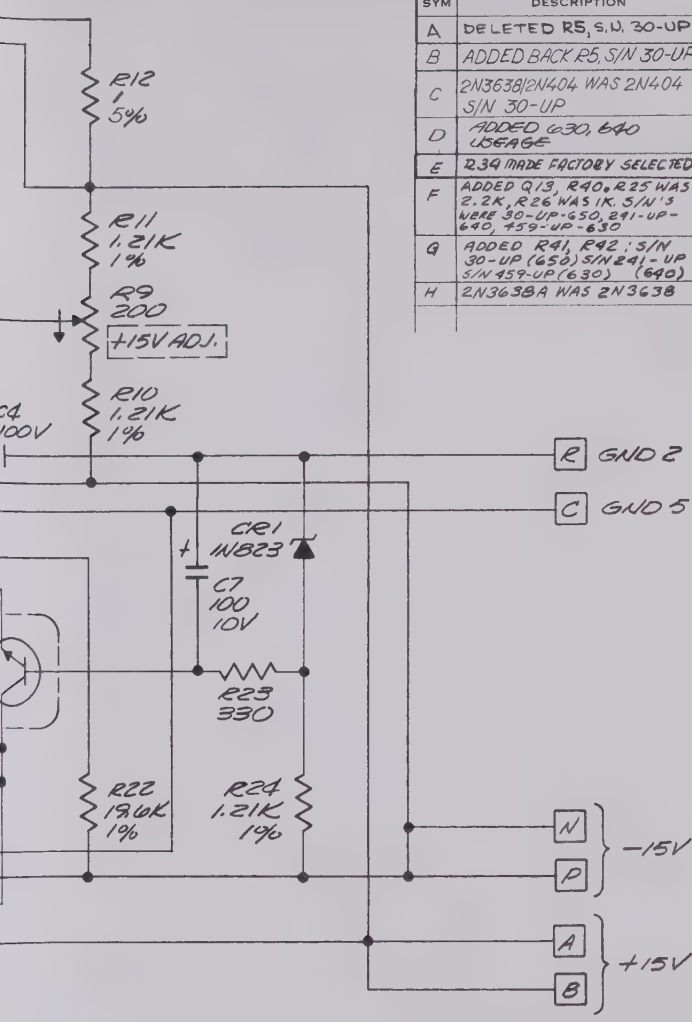
ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

900770C

SHEET 1 OF 1


SERIES TRANSISTOR Q3 COLLECTOR
Z
SERIES TRANSISTOR Q3 BASE
S
GND 2
Y
SERIES TRANSISTOR Q4 BASE
J
-15V INPUT SUPPLY (-)
K
SERIES TRANSISTOR Q1 BASE
U
GND 4
X
+100V
L
GND 3
H
SERIES TRANSISTOR Q2 BASE
E
-50V
D
R2 10K 2W, 5%
R3 15K
C1 .1 100V
R1 100
Q1 2N697
Q2 2N3638A
Q3 2N3638A
R4 19.6K 1%
R5 1 5%
C2 .1 100V
R7 19.6K 1%
C3 .1
R41 * 3.3K
Q4 950672/ SP9965 NS7301
R8 22
R6 19.6K 1%
R13 1.5K
C5 .1 100V
R34 * 10
Q5 2N3638A
R14 8.2K
R15 15K
R16 820
Q6 2N3638A
Q7 2N3638A
R17 750 1%
-15V ADJ.
R18 200
Q8 950672/ SP9965 NS7301
R19 1.21K 1%
C6 .01
R20 19.6K 1%
R21 19.6K 1%
R42 * 3.3K
Q13 2N699
R25 33K
R40 2.2K
Q9 2N3638A
R26 15K
R27 4.99K 1%
R29 470
R28 34K 1%
C8 10 100V
Q10 2N3638A
R39 15K
CR2 IN459
Q12 2N3250/ 2N3638A
CR3 IN459
R35 5.6K
R36 470
C10 .01
R37 100
R31 15K 1%
C9 .1
R30 470
R32 49.9K 1%
R33 100
Q11 2N697
R38 1.2K
* FACTORY SELECTED
ITEM
REQD
PART NO.
MATERIAL
MATERIAL STOCK NO.
FINISH OR TREATMENT

SYM	DESCRIPTION	NO.	DATE	BY
A	DELETED R5, S.N. 30-UP	12607	1-15-5	
B	ADDED BACK R5, S/N 30-UP	12607A	3-28-5	MN
C	2N3638/2N404 WAS 2N404 S/N 30-UP	12690	3-28-5	MN
D	ADDED 630, 640 USEAGE	12704	4-14-65	BD
E	2.34 MADE FACTORY SELECTED	12755	6-30-66	JHB
F	ADDED Q13, R40, R25 WAS 2.2K, R26 WAS 1K. S/N'S WERE 30-UP-650, 241-UP-640, 459-UP-630	12782	9-16-65	MS
G	ADDED R41, R42 ; S/N 30-UP (650) S/N 241-UP S/N 459-UP (630) (640)	12939	2-24-66	MS
H	2N3638A WAS 2N3638	12911	2-24-66	MS



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   1B. ALL 1% RESISTORS ARE METAL FILM TYPE
   1C. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT BOARD CONNECTION ON ASSY "A2", ASSY NO. 950818
3. PREFIX REFERENCE DESIGNATORS BY A2 (IE : A2R1, A2Q12)

6400
KS19974

S/N 271-UP	650
S/N 384-UP	640
S/N 459-UP	630
NEXT ASSY	USED ON

DESCRIPTION

LIST OF MATERIAL

DRAWN		DATE 11-16-64
ENG		12-16-64
PROD		12-15-64
SCALE		

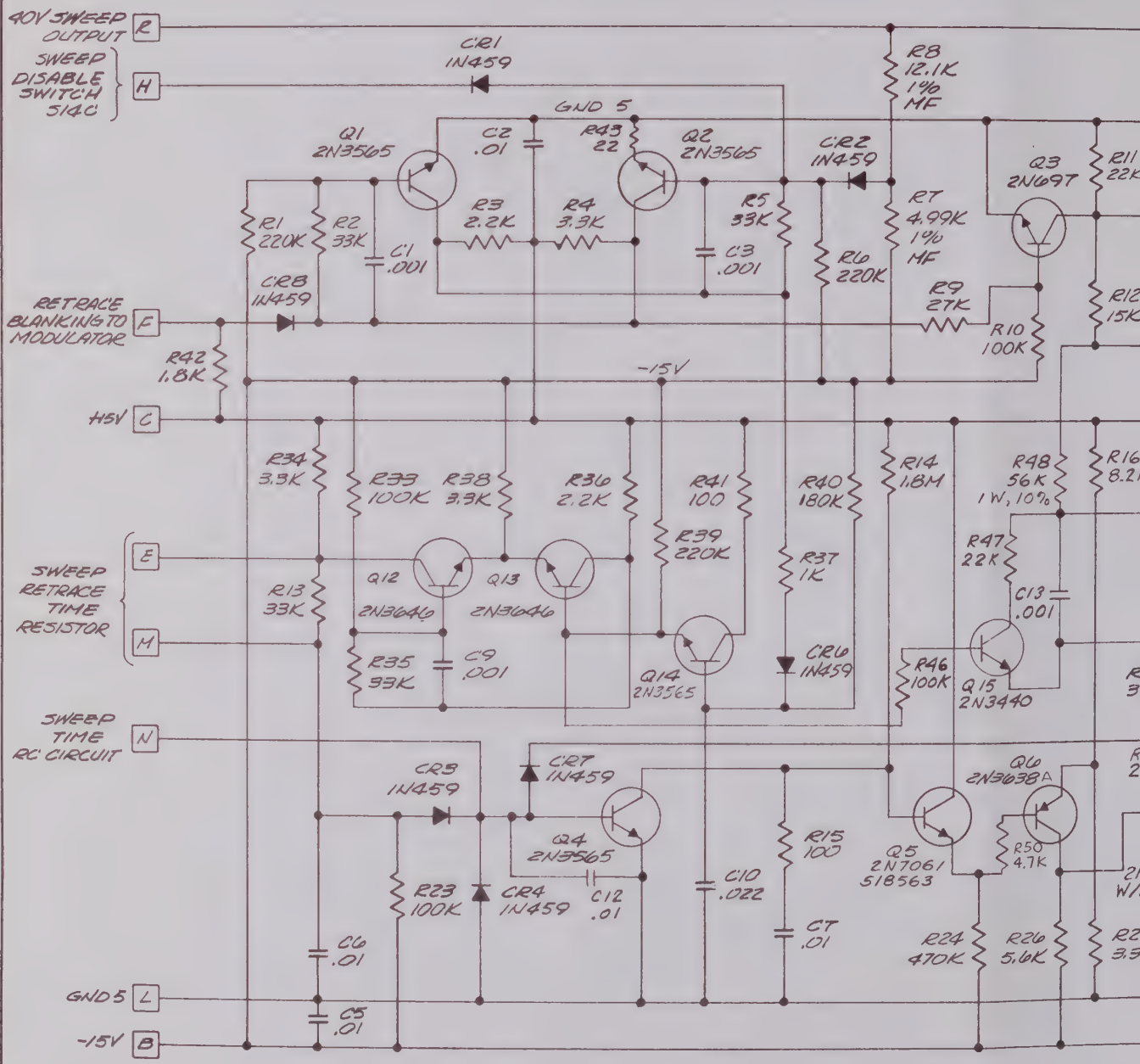
SCHEMATIC — LOW VOLTAGE POWER SUPPLY REGULATOR

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

9007666C-2

SHEET 1 OF 1



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - 1A. ALL RESISTOR IN OHMS, 1/2W, ±10%
   - 1B. ALL CAPACITOR IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A3", ASSEMBLY NO. 951045 (SN 11-UP)
3. PREFIX REFERENCE DESIGNATORS BY "A3" (I.E: A3R1, A3Q11)
4. REFER TO INSTRUCTION MANUAL FOR VALUE OF COMPONENT
5. P.C. ARTWORK NO. 944137.

* FACTORS

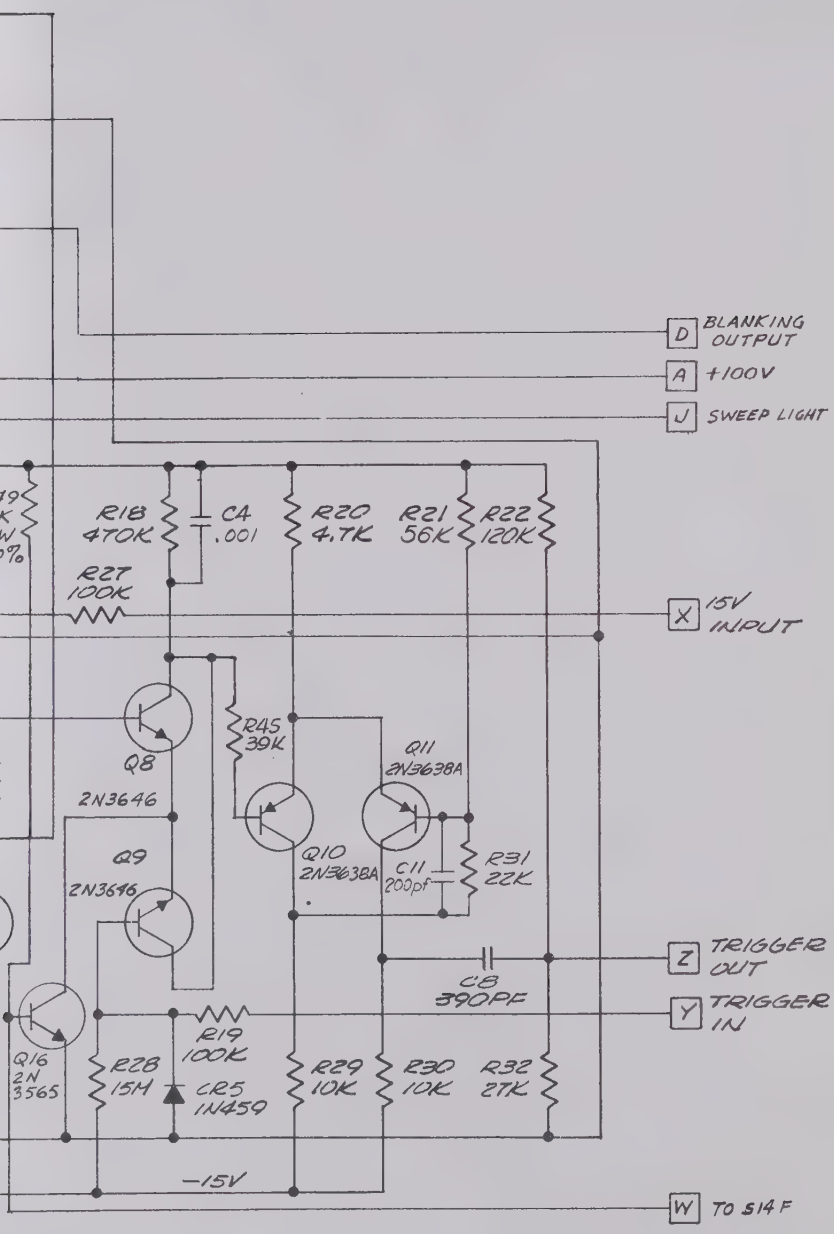
ITEM	REQD	PART N

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

SYM	DESCRIPTION	NO.	DATE	BY
A	R50 ADDED	13176	5/22/67	W.S.



LECTED

DESCRIPTION	
LIST OF MATERIAL	

	650
SER NO. 11-UP	6400
NEXT ASSY	USED ON

DRAWN	DATE
ENG	
PROD	
SCALE	

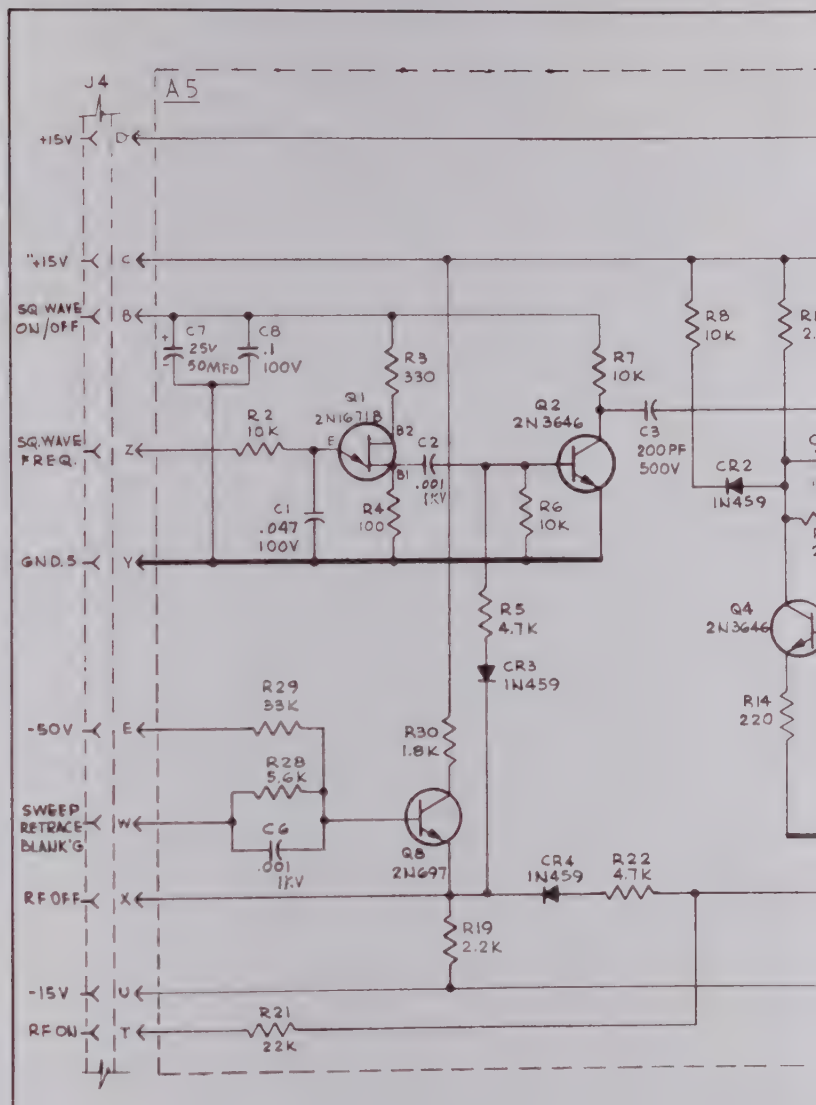
SCHEMATIC
SWEEP CIRCUIT
"A3"

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

C 900887 REV A

SHEET 1 OF

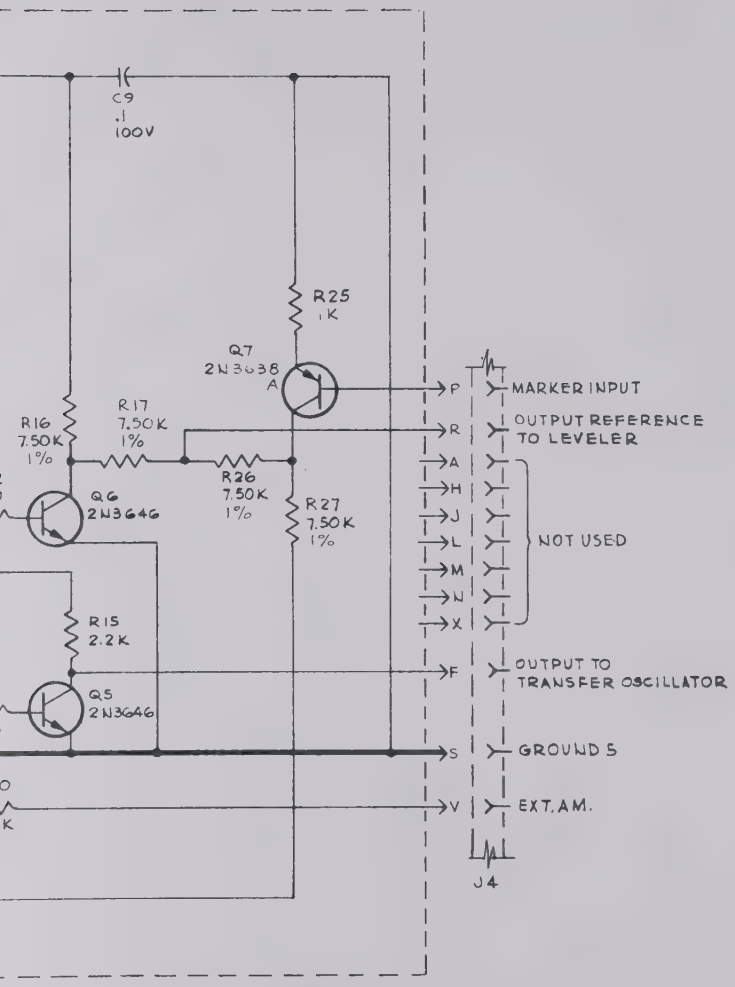


NOTES:

1. UNLESS OTHERWISE SPECIFIED
   A. ALL RESISTORS ARE IN OHMS, 1/2 W, 10%.
   B. ALL CAPACITORS ARE IN MICROFARADS.
2. PREFIX REFERENCE DESIGNATORS BY "A5".
3. REF. DWGS: ASSEMBLY - ML 950619

4. KEY BETWEEN PINS W AND X

SYM	DESCRIPTION	NO.	DATE	BY



PART NO	DESCRIPTION
	LIST OF MATERIAL

ML 950619	6400
ML 950619	650
NEXT ASSY	USED ON

DRAWN	DATE
I.M. SEEDMAN	3/17/67
ENG	
PROD	
SCALE --	

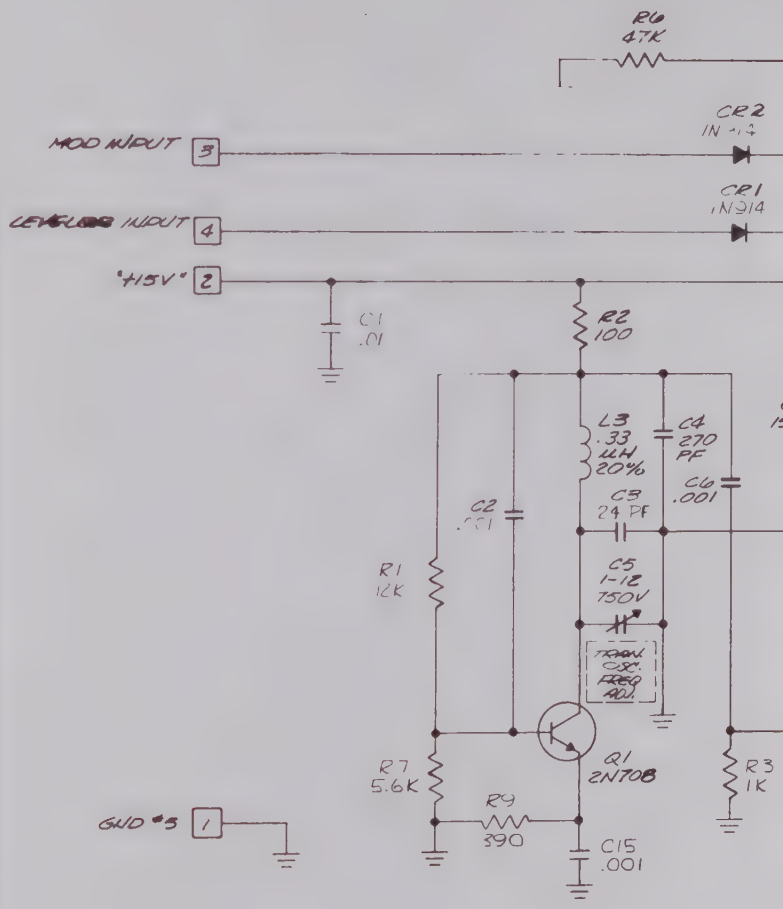
SCHEMATIC
MODULATION, CKT
A3

DIMENSIONS ARE IN INCHES
TOL XX ± .015 XXX ± .005 ANGLE ± ½
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

C 900714 REV E

SHEET 1 OF 1



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTOR IN OHMS, 1/2W, 10%
   1B. ALL CAPACITOR IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES TERMINAL CONNECTION
   ASSY "A9", ASSEMBLY NO. 950635
3. PREFIX REFERENCE DESIGNATORS BY "A9" (IE:
4. ARTWORK NO. 944056

SYM	DESCRIPTION	NO.	DATE	BY
A	ADDED TP12 & NOMENCLATURE ADDED NOMENCLATURE TO C5		8/15/66	cg
B	REPLACED L1 WITH A SHORT S/N 11 & UP	12657	3-25	JC
C	C3 MADE FACTORY SELECTED S/N 11 & UP	12719	4-30-65	MN
D	SCHEMATIC ERROR, TERM. 5 & 4 WERE SHOWN INCORRECTLY	12793	6-2-65	JC
E	ADDED L9, S/N 51 & UP	12774	7-28-65	JC
F	R1 WAS 33K S/N 11 & UP	12780	7-28-65	JC
G	C11 WAS 270, S/N 174 & UP	12799	8-17-65	MS
H	Q3, Q4 WERE 2N706 S/N 251 & UP	12831	9-28-65	MS
I	Q3 WAS 2N3565. S/N 251 & UP	12891A	11-22-65	MS
J	Q2 WAS 2N708, S/N 11-UP	13122	2-2-67	MS

C7 90, 6KV
T1
CR3 1N914
L6 18 UH
L7 18 UH
Q4 2N3643
6 GRID DRIVER
TP12 TRANSFER OSC. OUTPUT
Q3 2N3643
L4 2.2 UH 10%
C8 10 PF 5%
CR4 1N914
C11 5 PF 5%
C10 12 PF 2%
R4 1K
R5 82
R8 47K
CR5 1N459
Q2 2N3643
L5 4.7 UH
C14 .01
5 -100V SUPPLY
C9 30 PF 6KV
C12 .001 6KV
7 ϕ LINE

650 - 1491 & UP
6400 - 156 & UP

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

950635	6400
950635	650
NEXT ASSY	USED ON

MATERIAL
MATERIAL STOCK NO
FINISH OR TREATMENT

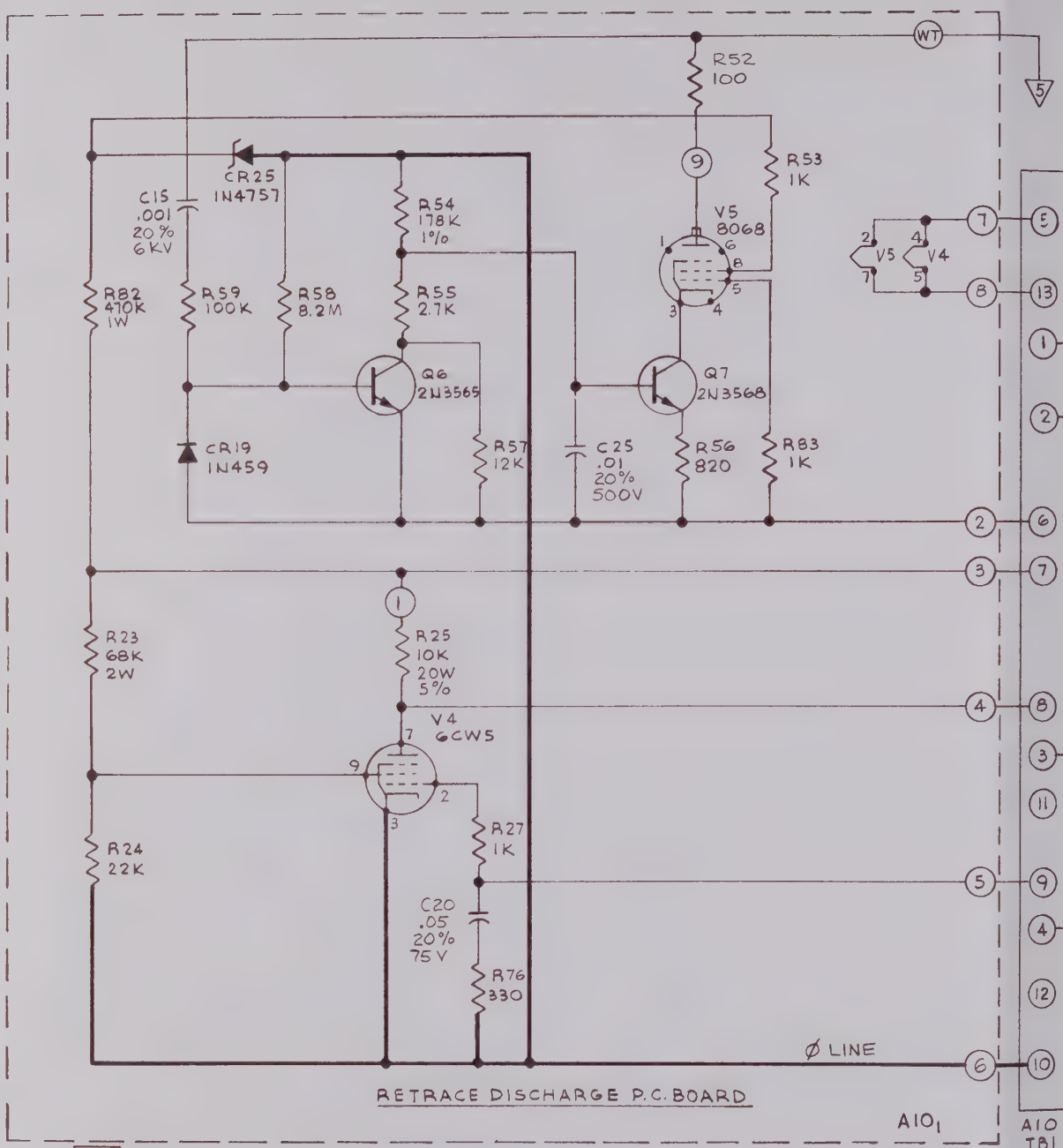
DRAWN — DATE 8/18/64
ENG
PROD
SCALE

SCHEMATIC
IRANSFER
OSCILLATOR

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE C 900747 REV R
SHEET 1 OF 1



A10 TB1

1	→ T1-6
2	→ T1-5
3	→ A1-D (CATHODE SUPPLY)
4	→ +100V
5	→ T1-16A
6	→ -100V
7	→ A15-19 (RECTIFIER ASSY) & C80+
8	→ A6-12 (AUX SUPPLY
9	→ A6-10 (AUX. SUPPLY)
10	→ A6-9 (AUX. SUPPLY) & C80-, & A15-18 (RECTIFIER ASSY)
11	
12	
13	→ T1-16

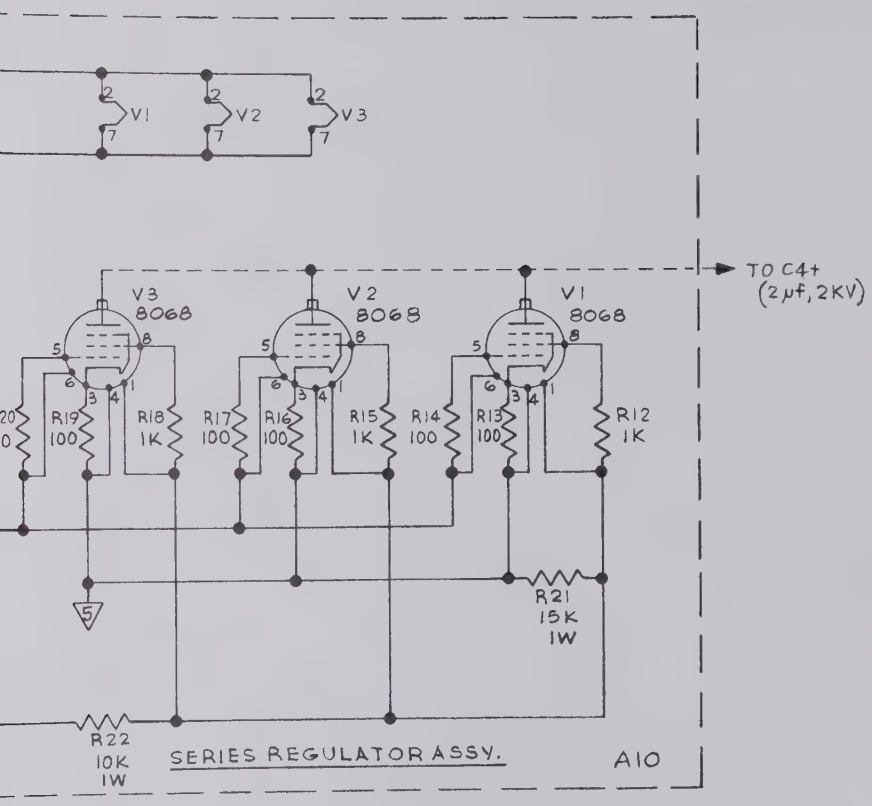
ITEM	REQD

MATERIAL

MATERIAL STOCK NO.

FINISH OR TR

SYM	DESCRIPTION	NO.	DATE	BY
—	PROD RELEASE			
A	ECO INCORP	13281	11-21-7	CHN DUCK



NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL CAPACITORS IN MFD.
2. ALL RESISTORS IN OHMS, 1/2W, ±10%
3. PREFIX REF. DESIGNATORS BY "A10"

NO.	DESCRIPTION
	LIST OF MATERIAL

951082	6400,650
951083	6400,650
NEXT ASSY	USED ON

DRAWN I.M.SEEDMAN 5/19/67
ENG
PROD

SCHEMATIC
SERIES REGULATOR/RE-TRACE DISCHARGE ASSY.
"A10"

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

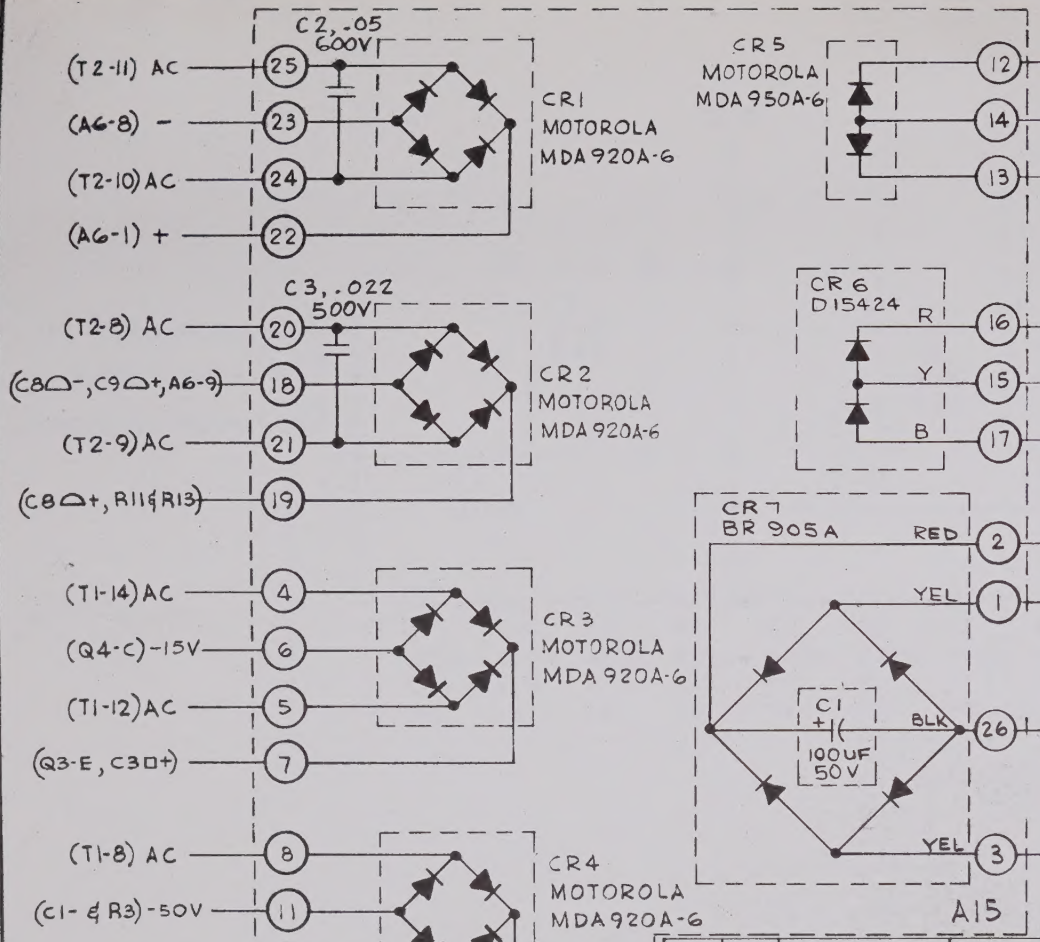
SIZE C | 900906 | REV A

SCALE —

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
B	C1 WAS 25 μF.			
C	REPLACED CR 6,7,8, & 9 WITH UNITIZED ASSEMBLIES	13212	5 SEPT 67	CWK
D	(AG-3) WAS X, (T1-15); (T1-15) WAS – (AG-3)	13219	13 SEPT 67	JMS (JPL
E	REVISED	13711	8 JAN 68	MS



NOTES:
1. PREFIX REFERENCE DESIGNATORS BY "A15" (i.e., A15 CR1, A15 C1, ETC.)

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

951061	650
951061	6400
NEXT ASSY	USED ON

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN I.M.SEEDMAN 3-23-67

ENG

PROD

SCALE

SCHEMATIC RECTIFIER ASSEMBLY A15

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

B 900905 REV E

SHEET 1 OF 1